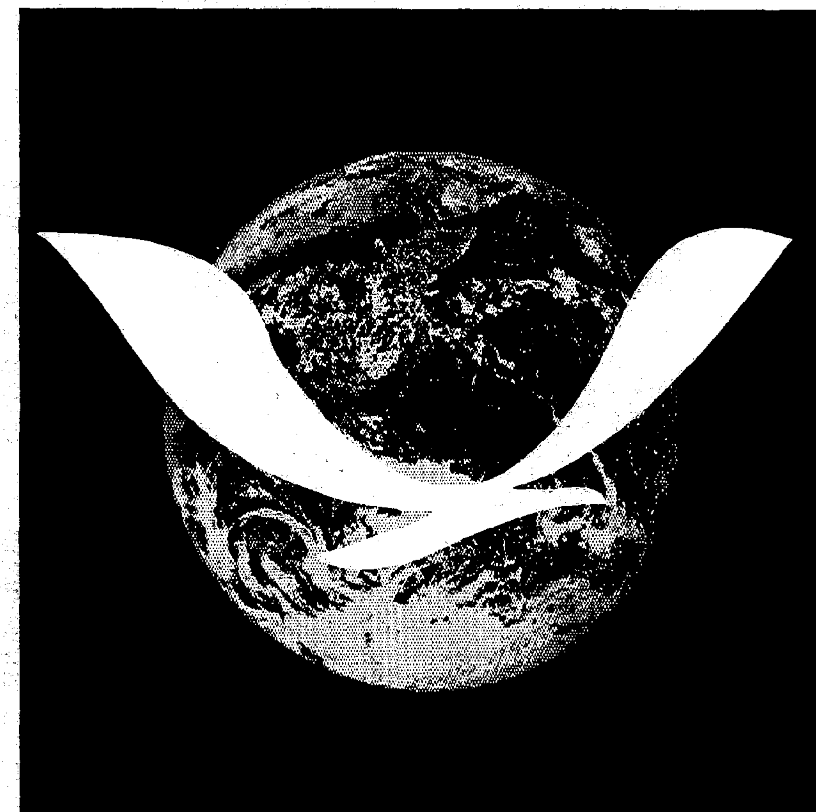
NOAA ENVIRONMENTAL DIGEST

Selected Indicators of the United States and the Global Environment



December 1991

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

Office of the Chief Scientist

ABOUT THIS REPORT

The NOAA ENVIRONMENTAL DIGEST is a regular report of environmental data and information collected by NOAA. This report provides a selected summary of NOAA data considered useful to the scientific community for a variety of applications. The goal of the report is to present the facts, and to leave the interpretation to others. The data presents past trends only; no forecast is implied.

The report has been developed and produced by the NOAA Office of the Chief Scientist. The Office welcomes comments, critiques, and suggestions for improvement. Inquiries and commentaries about the report should be directed to Dr. Joseph M. Bishop, NOAA Office of the Chief Scientist, Herbert Clark Hoover Building, 14th and Constitution Avenue, N.W., Washington, DC 20230; (202) 377-0531.

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Selected Indicators of the United States and the Global Environment

December 1991

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary

Office of the Chief Scientist
Sylvia A. Earle, Chief Scientist

ACKNOWLEDGMENTS

This report represents the work of numerous scientists throughout the National Oceanic and Atmospheric Administration (NOAA). Without their cooperation the NOAA ENVIRONMENTAL DIGEST would not be possible. A sincere thanks is extended to the contributors for the excellent summaries of their work provided. Drafts of this report were reviewed by a number of individuals throughout the agency and their constructive comments were of great help. The project team for this report (Dr. Joseph M. Bishop [Project Leader], Mr. John L. Wickham [Project Coordinator], and Dr. Isobel C. Sheifer [Editor]) gratefully appreciates the efforts of all those who contributed to this endeavor.

INTRODUCTION

The Earth's environment is continually being modified by human activities and natural processes. These changes may have profound effects on our health, global ecology, and the economic welfare of nations.

With the creation of NOAA, the nation established a unique agency dedicated to the enhancement of knowledge about our environment. NOAA's core mission is to increase understanding of the total Earth system, an understanding based on effective monitoring of the global environment. NOAA currently monitors the Sun, atmosphere, ocean, biosphere, and cryosphere on regional to global spatial scales and synoptic to climatological time scales.

To assist in the understanding of environmental change, and to aid in the assessment of its global implications, a NOAA ENVIRONMENTAL DIGEST has been instituted. The NOAA ENVIRONMENTAL DIGEST has two primary objectives. The first is to document, on a regular basis, changes in selected environmental variables. The second is to provide information to those engaged in the development of relationships between environmental change and its consequences to society.

The wide diversity of data collected by NOAA is published in numerous reports, bulletins, journals, and the scientific literature. This report was initiated in an attempt to make this diverse collection of data more accessible, publicize its presence, and promote an awareness of environmental variability and climatic change. The NOAA ENVIRONMENTAL DIGEST focuses on selected environmental parameters considered indicators of system variability.

The material presented in this report has been provided by scientists from each of the five NOAA Line Offices: the National Ocean Service, the National Weather Service, the National Marine Fisheries Service, the National Environmental Satellite, Data, and Information Service, and the Office of Oceanic and Atmospheric Research. A listing of NOAA offices providing additional information on a specific parameter is given in Appendix B.

SELECTED ENVIRONMENTAL INDICATORS

The global environment is an inter-related system that includes the atmosphere, oceans, ice, and biota. These components are coupled through a complex, even chaotic, combination of biological, chemical, and physical processes, occurring over the spectrum of time and space scales. The natural coupling of these processes requires that the Earth be studied in an interdisciplinary fashion as a single system with global dimensions. With this in mind, it was nevertheless convenient for the purposes of this report to divide the global environment into the categories of atmosphere, ocean, cryosphere (ice), and biosphere. The parameters presented in this report were chosen because of their potential influence on the global environment or because they are considered indicators of system change, either on regional or global scales.

In the first edition of the NOAA ENVIRONMENTAL DIGEST a wide-range of environmental variables were presented. In this second edition many of these time series are continued. New variables such as wetlands, salinity, a vegetation index, and zooplankton have been added. The protected resources section has been expanded to include sea turtles, habitat conservation, and the preservation of significant marine and estuarine ecosystems. Also, a section on major environmental events involving NOAA during the last year has been added. As with the first edition, the Office of the Chief Scientist welcomes comments and suggestions for improving the document.

CONTENTS

LIST OF FIGURES

LIST OF FIGURES--continued

LIST OF FIGURES--continued

LIST OF FIGURES--continued

LIST OF FIGURES--continued

LIST OF TABLES

I. ATMOSPHERE

The atmosphere is a complex and ever-evolving component of the Earth system. It interacts, with various degrees of predictability, with the oceans, cryosphere, and biosphere. The atmosphere influences many processes within the Earth system and serves as our prime indicator of changes in global climate. The atmospheric parameters presented in this report were chosen because they are considered to be sensitive to, or indicators of, changes in the total Earth system.

AIR TEMPERATURE

Over recent years air temperature has been used as the primary indicator of global climate change. Time-series records, maintained for over a century at some stations, indicate periods of stable or even declining temperatures. A warming trend, one that started in the late 1970s, has been a significant characteristic of the recent record. Changes in global mean air temperature have been associated with changes in atmospheric composition (especially greenhouse gases, aerosols, and cloudiness), the ocean, sea ice, and snow cover. Increased understanding of the variability in this record will be critical in separating anthropogenic effects from natural variability.

Global mean air temperature has historically been estimated from surface (land) temperature records, primarily from meteorological stations in the Northern Hemisphere. The problems of sparse, nonuniform distribution of observational sites, instrumentation changes and relocations, and the influence of urban heating on sites have added uncertainty to the estimation of the global mean temperature.

Mean upper air temperatures have been traditionally determined from radiosonde and rocketsonde observations. Satellite-derived global temperature data (available since 1978) are providing an additional data source which has been especially useful for meeting ocean and upper air needs.

a. Surface

i. Global Averaged Distribution

Global surface temperatures for the decade of the 1980s averaged above normal. Temperature anomalies show almost all areas of the Northern Hemisphere experienced warmer values than the 1951-1980 base period average. Only Greenland and Baffin Island experienced negative anomalies. The largest positive anomalies were found over the central and eastern Soviet Union, Alaska, and western Canada. The Southern Hemisphere also experienced above-normal temperatures, except for a small area in central America.

A four-decade-long time series of the globally averaged land anomaly indicates positive values during the 1980s (Figure I-1) with the exception of the slight negative value for 1985. Median temperature anomalies in the latter half of the 1980s were clearly more positive than those measured earlier in the record. The median value for 1990, 0.5°C, was higher than any other median value in the time series. Approximately half of the global land area for 1990 had average temperature anomalies of 0.5°C or greater. The year was also notable because only slightly more than 10 percent of the world's land area experienced negative anomalies.

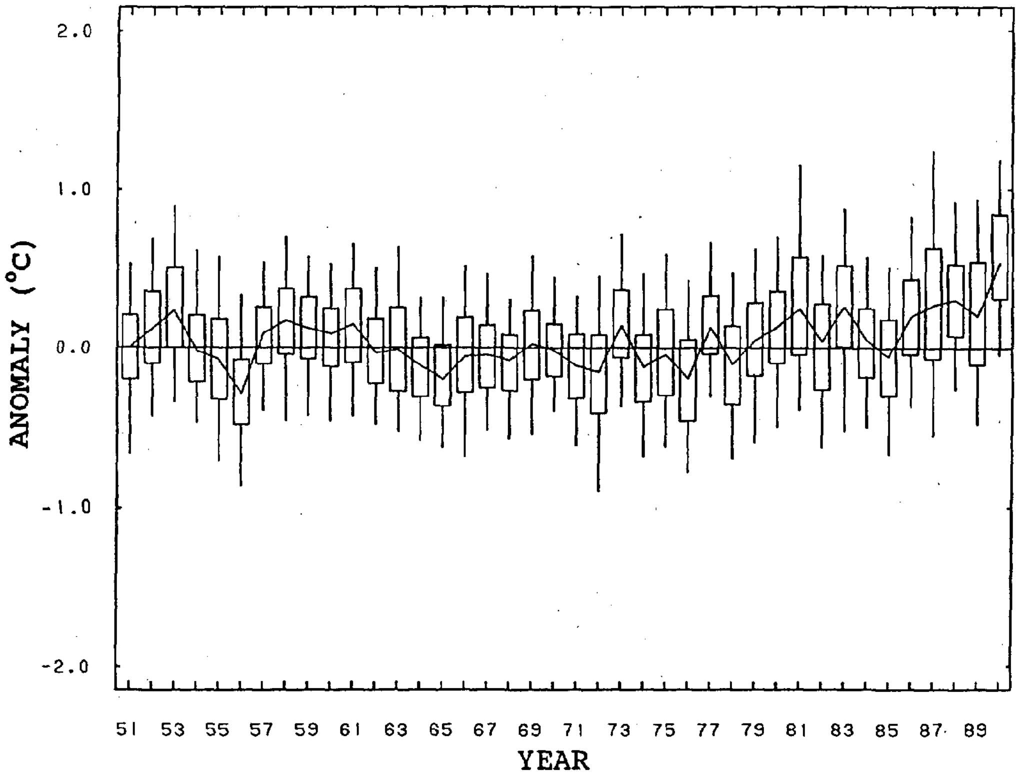


Figure I-1. Mean global land temperature anomaly (°C) based on the average annual temperature anomalies in 2° latitude by 2° longitude areas. The solid line represents the 50 percent, or median, temperature anomaly for each year. Each "box" delineates the temperature anomalies at the 70th and 30th percentiles while the "lines" delineate the 90th and 10th percentile values. The anomalies are with respect to the 1951-80 base period. (Courtesy Climate Analysis Center, NOAA National Weather Service)

The Northern Hemisphere time series (Figure I-2a) is almost identical to the global series since most of the land area, as well as most of the surface data, are located in the Northern Hemisphere. It is somewhat surprising, however, that the overall character of the Southern Hemisphere temperature time series (Figure I-2b) is very similar to the Northern Hemisphere series. Both hemispheres show the 1980s to be warmer than earlier decades. One difference is that the Southern Hemisphere median temperatures for 1980 and 1988 are both larger than those for 1990. The Southern Hemisphere also shows closer relationships to the Southern Oscillation, with each of the warm episode years showing positive median temperature anomalies (except 1965) and each of the cold episode years showing below median anomalies (except for 1988). The two coldest years in the Southern Hemisphere series, 1956 and 1975, are associated with cold Southern Oscillation episodes.

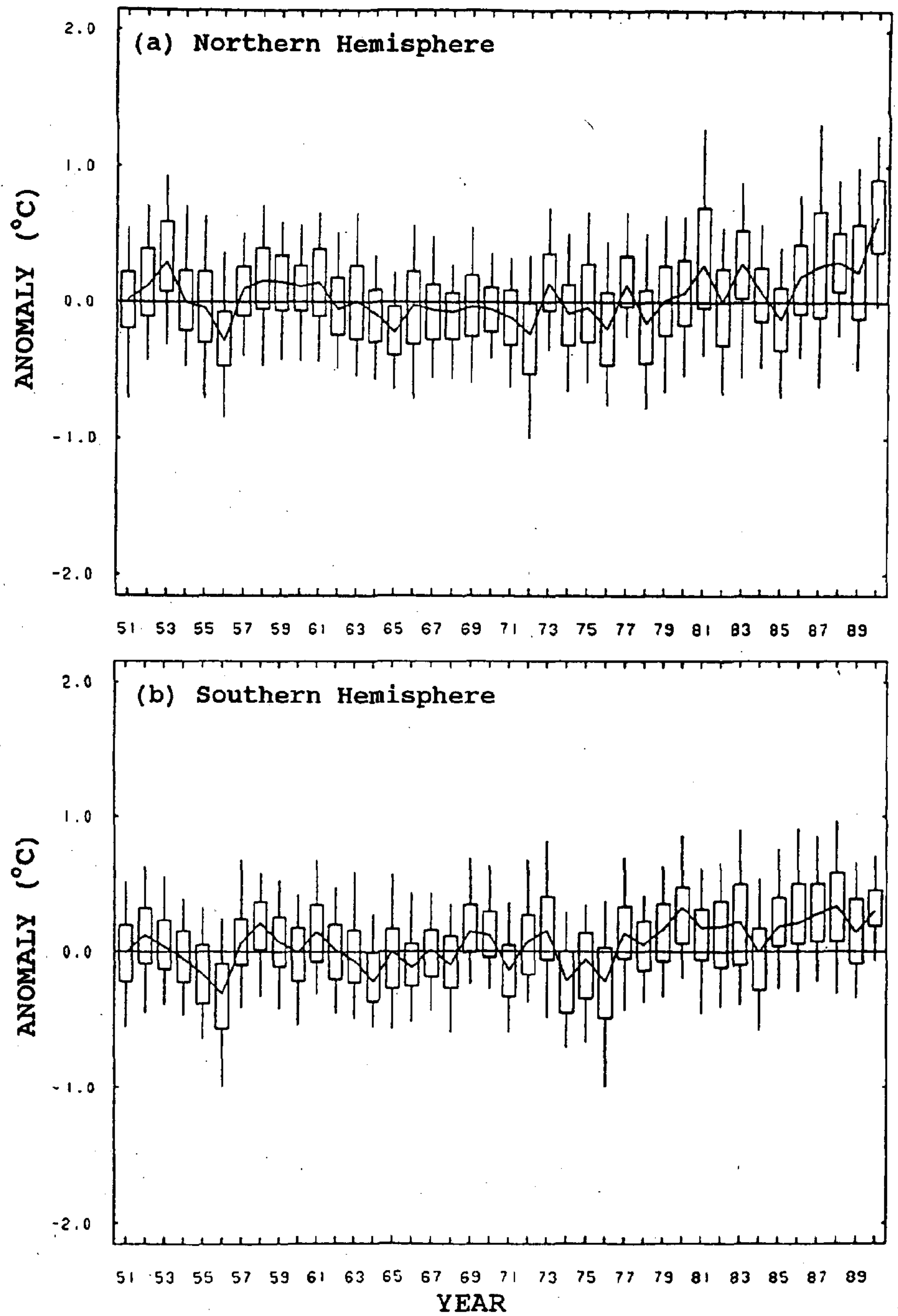


Figure I-2 (a)-(b). (a) Northern Hemisphere and (b) Southern Hemisphere surface temperature index based on the average annual temperature anomalies in 2° latitude by 2° longitude areas over land. The solid line represents the 50 percent, or median, temperature anomaly for each year. Each "box" delineates the temperature anomalies at the 70th and 30th percentiles while the "lines" delineate the 90th and 10th percentile values. The anomalies are with respect to the 1951 to 1980 base period. (Courtesy Climate Analysis Center, NOAA National Weather Service)

ii. United States

In the United States, the decade of the 1980s ranks as the second warmest of the century, behind the 1930s and just ahead of the 1950s (Figure I-3). Figure I-3 shows the time series of the mean annual temperature for the contiguous United States from 1895 through 1990 computed by area-weighting the annual temperatures for 344 climatic divisions. Although the decade as a whole averaged well above normal, half of the years experienced mean temperatures below the long-term mean. However, the warmth during 1981, 1986, 1987, and 1990, which all averaged greater than 1.0°C above normal, resulted in a much warmer than average decade. Although the last half of the 1980s averaged considerably above the long-term mean (the horizontal line), the filtered curve indicates that it rivals, but was not hotter than, the 1930s. Annual temperature for 1990 ranked the year as the seventh warmest on record.

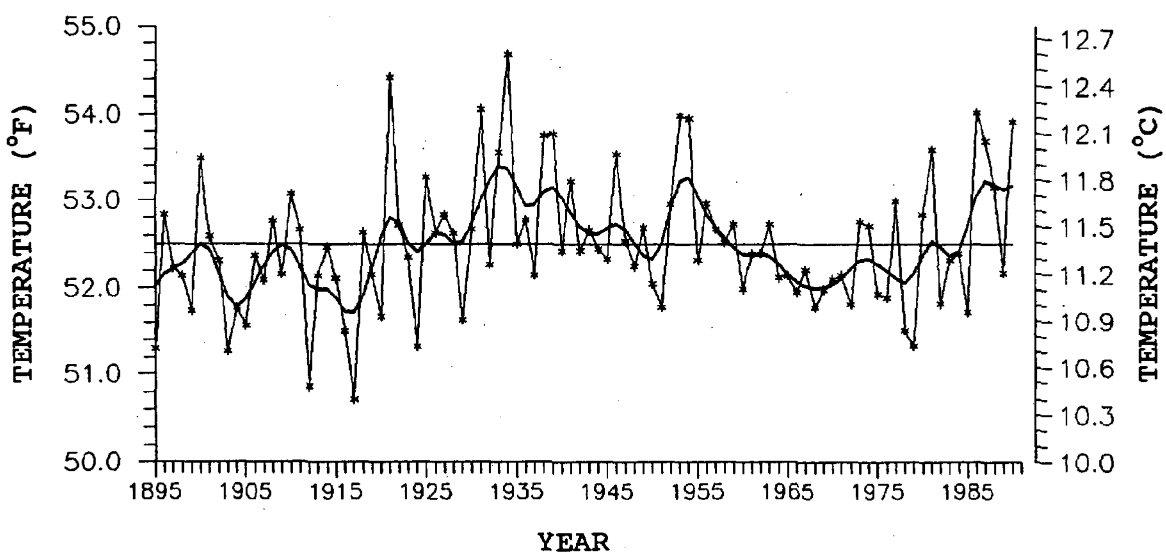


Figure I-3. United States annual average temperature and the filtered curve for 1895-1990. The horizontal line indicates long-term mean over the whole record. (Courtesy Richard R. Heim, Jr., National Climatic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

b. Upper Air

The time series of mean 850-350 mb temperature anomaly derived from radiosonde data (Figure I-4) agrees with the surface temperature record. In this time series, 1990 appears to be the warmest year in the 33-year record (1958 to 1990). The positive temperature anomalies of 1982, and 1987-88 have been attributed to the El Ninos in those years.

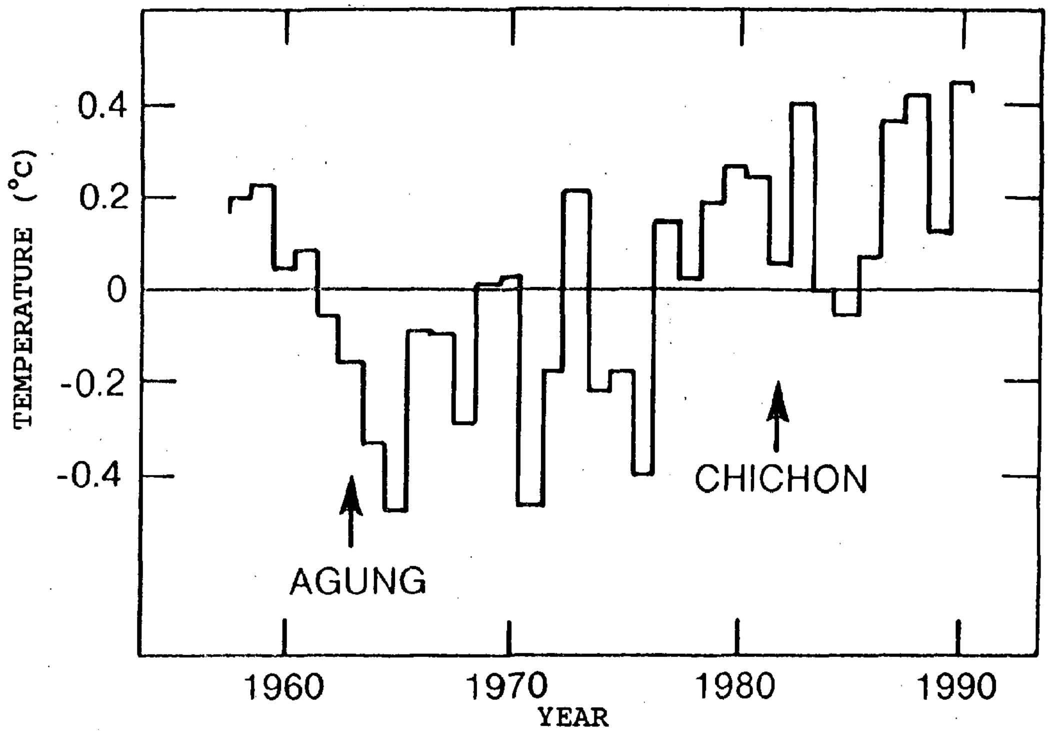


Figure I-4. Time series of global 850-300 mb temperature anomaly derived from radiosonde data. Agung and Chichon are volcanos whose eruptions correlate with tropospheric cooling. (Courtesy James K. Angell, Air Resources Laboratory, NOAA Office of Oceanic and Atmospheric Research)

TRACE GASES

The atmosphere consists mainly of nitrogen (78 percent), oxygen (21 percent), argon (1 percent), and water vapor (0-4 percent). In addition, several atmospheric trace gases (e.g., ozone, methane, nitrous oxide, chlorofluorocarbons, and carbon dioxide) play an important role in the absorption of solar and/or terrestrial radiation. Over geological time, trace gases, have acted as a thermostat forming a natural greenhouse that allowed Earth's climate to remain favorable for human habitability.

a. Carbon Dioxide

Carbon dioxide (CO_2) is an essential component of the Earth's carbon cycle that governs vital processes in the ocean, atmosphere, and on land. The increased burning of fossil fuels since the Industrial Revolution has been linked to increased concentrations of atmospheric CO_2 and has caused concern regarding its potential to produce global-scale climate changes. Changes in atmospheric CO_2 are a result of complicated interactions between the atmosphere, oceans, and the annual cycle of photosynthesis. As part of the work of the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL), continuous CO_2 measurements have been made since the early 1970s at the NOAA baseline observatories at Barrow, Alaska; Mauna Loa, Hawaii; Pago Pago, American Samoa; and South Pole, Antarctica. These observations indicate increasing global CO_2 concentrations. This trend is illustrated in Figure I-5, where the complete record (1958-1990) of CO_2 measurements from Mauna Loa is presented. The data through 1972 were compiled by the Scripps Institution of Oceanography (Professor C.D. Keeling) and by NOAA/CMDL thereafter. The observed increase has been linked to fossil fuel combustion, changes in the amount of CO_2 held in standing biomass and soils, and global scale phenomena such as El Nino, which cause interannual variations in the CO_2 growth rate. The mean growth rate for the last four years was about 1.7 parts per million per year.

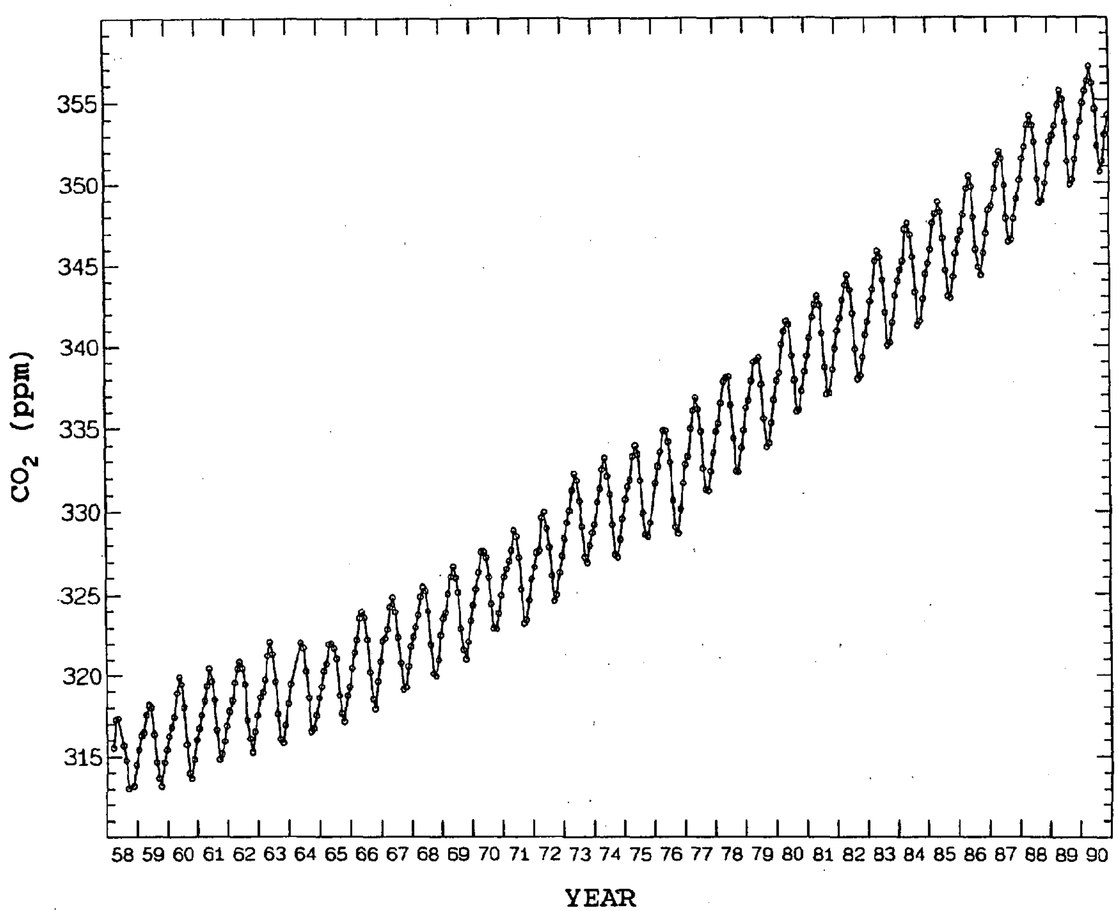


Figure I-5. Monthly mean CO_2 concentrations in parts per million (ppm), 1958-1990, at Mauna Loa, Hawaii. (Courtesy Kirk Thoning, Climate Monitoring and Diagnostics Laboratory, NOAA Office of Oceanic and Atmospheric Research)

In addition to measurements at the baseline observatories, NOAA/CMDL collects flasks of air, once per week, at 30 globally-dispersed cooperative sites. The flasks are returned to their Boulder laboratory for analysis of CO_2 concentration. From these data, a global carbon dioxide growth rate is determined by averaging the growth rates, weighted by latitude, from each of the flask CMDL network stations.

Figure I-6 shows the results of this analysis in terms of the rate of atmospheric CO_2 increase as a function of time during the period 1981-1990. The largest growth rate variations (1982-83; 1987-88) are associated with the El Nino/Southern Oscillation (ENSO) events, but the mechanism responsible for this connection is not clearly understood. The mean CO_2 growth rate for 1981-1990 is about 1.4 parts per million per year.

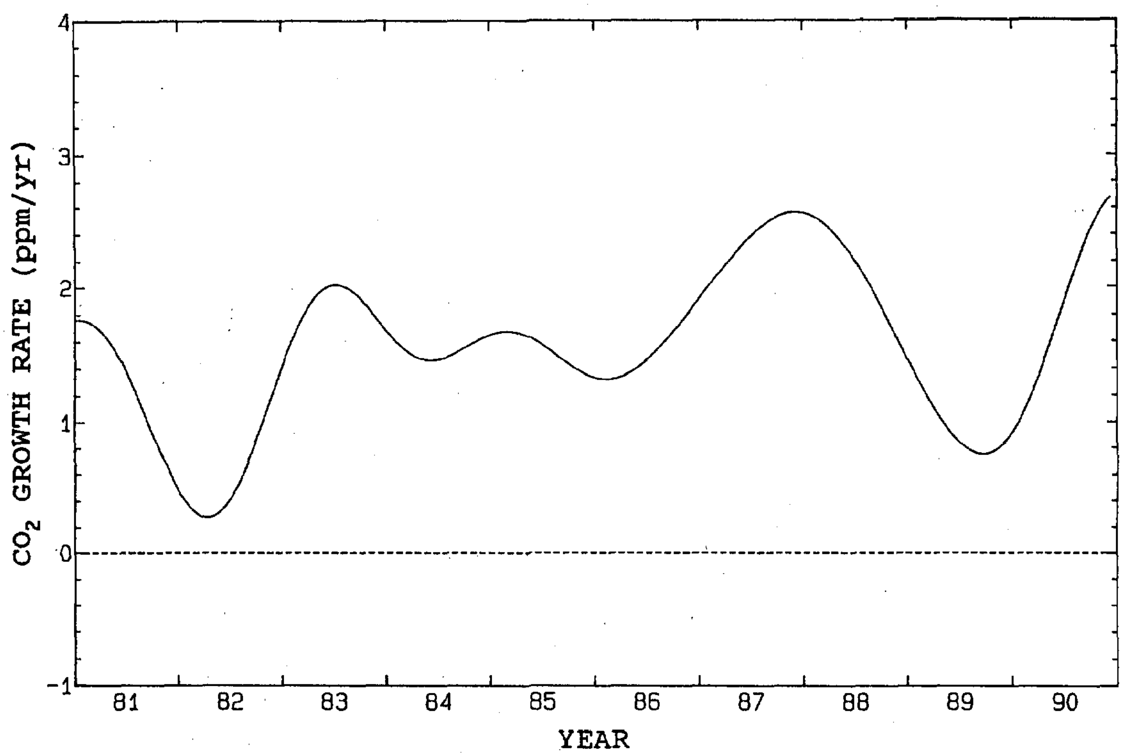


Figure I-6. Global average CO_2 growth rate in parts per million /year (ppm/yr), 1981-1990, from NOAA/CMDL flask network. (Courtesy Thomas Conway, Climate Monitoring and Diagnostics Laboratory, NOAA Office of Oceanic and Atmospheric Research)

In Figure I-7, the annual CO_2 mixing ratios for sampling sites of the NOAA/CMDL flask sampling network are plotted versus sine of latitude for the period 1981-1990. This figure highlights several

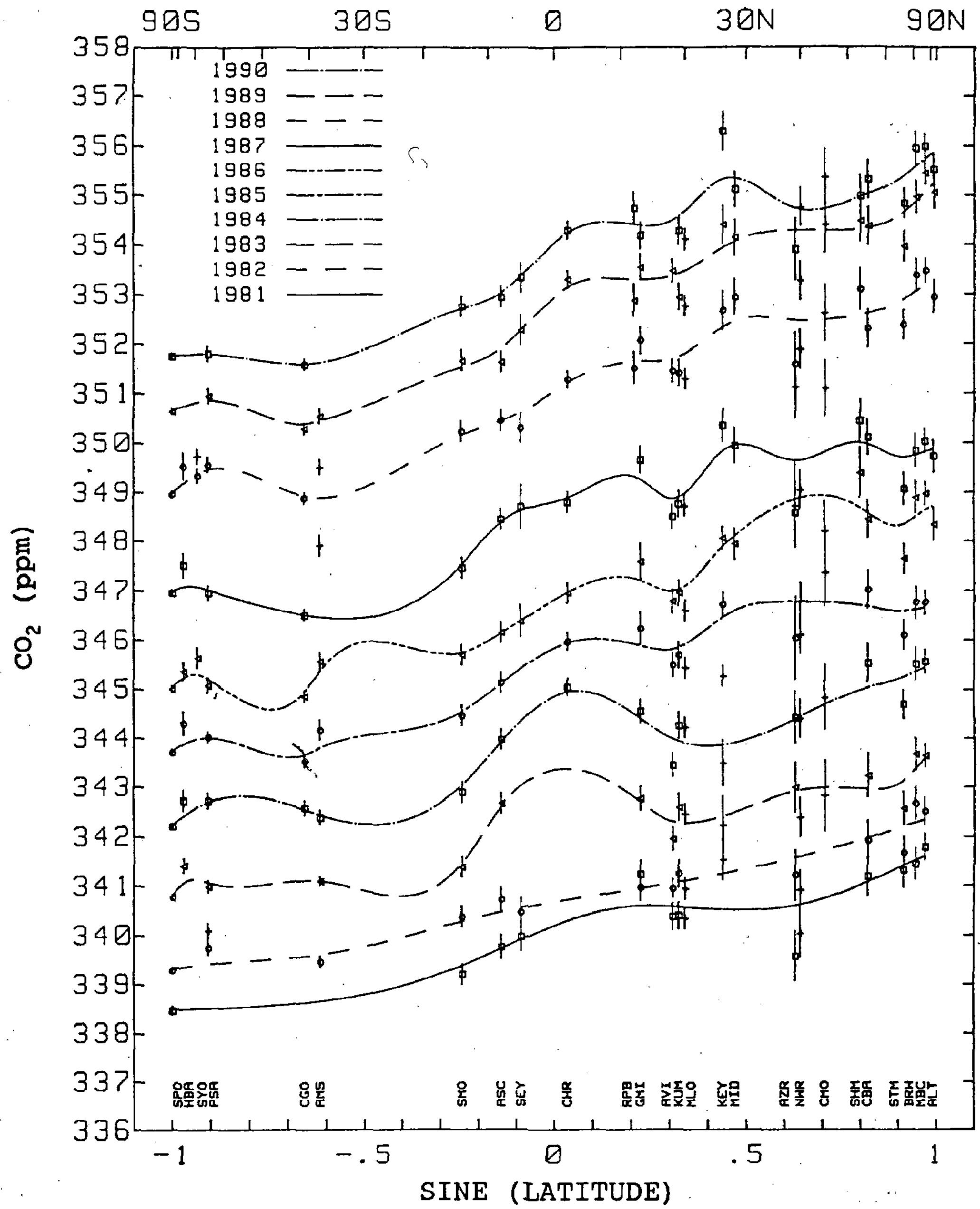


Figure I-7. CO_2 in parts per million (ppm) vs. sine of latitude for 1981-1990. Stations: SPO (South Pole), HBA (Halley Bay), SYO (Syowa), PSA (Palmer Sta.), CGO (Cape Grim), AMS (Amsterdam I.), SMO (Samoa), ASC (Ascension I.), SEY (Seychelles), CHR (Christmas I.), RPB (Barbados), GMI (Guam), AVI (Virgin I.), KUM (Kumukahi), MLO (Mauna Loa), KEY (Key Biscayne), MID (Midway), AZR (Azores), NWR (Niwot Ridge), CMO (Cape Meares), SHM (Shemya I.), CBA (Cold Bay), STM (Station M), BRW (Barrow), MBC (Mould Bay), ALT (Alert, NWT). (Courtesy Thomas Conway, Climate Monitoring and Diagnostics Laboratory, NOAA Office of Oceanic and Atmospheric Research) important features of the atmospheric CO_2 distribution and the global carbon cycle. First, there is a mean north-south CO_2 gradient. Carbon dioxide concentrations in the Northern Hemisphere are higher because fossil fuel CO_2 emissions occur predominately in this hemisphere. Second, the atmospheric CO_2 concentration is increasing. The average rate of increase from 1981-90 is 1.4 ppm/yr. Third, the rate of increase varies significantly from year to year. This variability is too large to be explained by variations in anthropogenic CO_2 emissions. The largest interannual variations occur in association with ENSO events, but the mechanism responsible for these variations is not clearly understood. Fourth, the shape of the mean latitude gradient changes from year to year. These variations result from changes in the global carbon cycle, i.e., the exchanges of carbon between the atmosphere and the ocean, and between the atmosphere and the terrestrial and marine biospheres. Finally, the north-to-south pole CO_2 difference has increased from ~3 ppm during 1981-87 to ~4 ppm during 1988-90. This shift may be due to an increasing sink or decreasing source in the Southern Hemisphere, or a combination of these. The data suggests that the Southern Hemisphere sink and the northern tropical source have both increased.

b. Ozone

Ozone (O_3), produced photochemically in the stratosphere by the disassociation of oxygen molecules, is a natural greenhouse gas 90 percent of which is found in the stratosphere. Ozone shields the biosphere from the damaging effects of ultraviolet radiation by selectively absorbing it in this portion of the solar radiation spectrum. In addition, ozone-producing reactions heat the stratosphere and may even have an influence on global climate. Ozone is destroyed naturally by reaction with the hydroxyl radical (OH) and oxides of chlorine, nitrogen, and bromine. Recent observations of significant declines in ozone over Antarctica have been attributed to the destruction of ozone by chlorine atoms of halogenated hydrocarbons.

Monthly averaged global ultraviolet data from the Nimbus-7 satellite beginning in November 1978 and extending to September 1986 have been combined with data from the NOAA-9 and -11 satellites from March 1985 to May 1990. Each data set is adjusted to ground-based data to evaluate the ozone trend over the total time period. The combined time series from each satellite is shown in Figure I-8.

Long-term ozone trends have been monitored with Dobson ozone spectrophotometers at NOAA/CMDL observatories at Mauna Loa (MLO), Hawaii (19.5°N, 155.6°W), since 1964, and at Samoa (SMO), South Pacific (14.3°S, 170.6°W), since 1975. Prior to 1976, ozone in Hawaii increased at a rate of 0.32 +/- 0.14 percent per year.

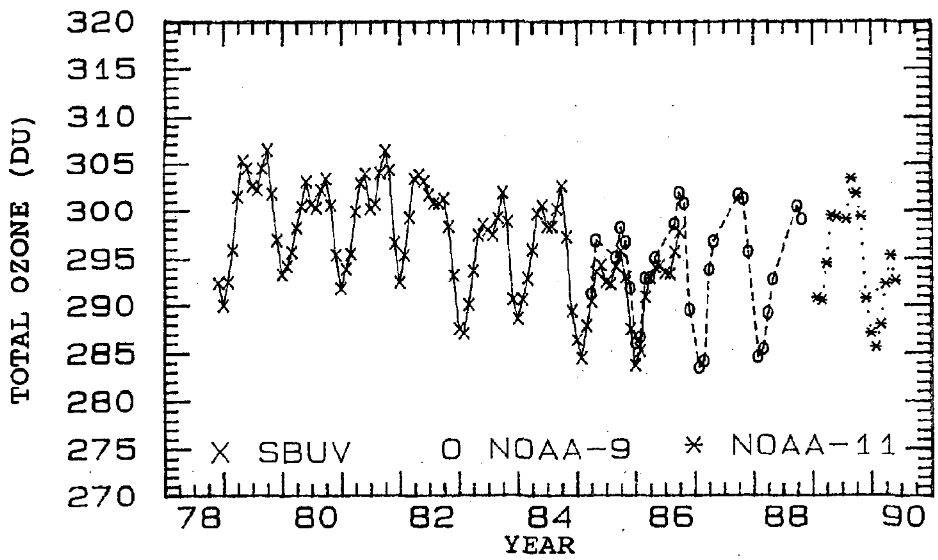


Figure I-8. Time series of monthly averaged total ozone (60°N-60°S) in Dobson units (DU) from November 1978 through May 1990. The overlap period extends from March 1985 to September 1986. One DU=10^{-3}cm of ozone at standard temperature and atmospheric pressure. (Courtesy Walter G. Planet, Satellite Research Laboratory, NOAA National Environmental Satellite, Data, and Information Service)

Figure I-9 shows plots of ozone anomalies (i.e., deviations of ozone monthly means from monthly normals) at MLO and SMO for 1976 through August 1990. Quasi-biennial oscillations in ozone are clearly evident in the record. Least-squares linear regression trend lines fitted to the data indicate that during 1976-1987 ozone decreased at MLO at a rate of 0.27 +/- 0.15 percent/year, while at SMO it decreased at a rate of 0.41 +/- 0.11 percent/year. Ozone suddenly increased at SMO in June 1988 to levels previously observed there in the mid-1970s, while at MLO ozone began to increase later in 1988. These data indicate no statistically significant trends in ozone at the two stations.

The dramatic rise in ozone at SMO in June 1988 coincided with a sudden decrease in eastern equatorial Pacific sea surface temperatures to low values previously observed there in 1976. On average, sea surface temperatures in the eastern equatorial Pacific were 0.7°C warmer during 1976-June 1988 than they were during 1962-1975. The initial downward trends in ozone at MLO and SMO followed by ozone recovery, shown in Figure I-9, exemplify the complex interaction between ozone depletion from halocarbons and ozone changes from natural processes, such as sea surface temperature-induced atmospheric circulation changes and changes in solar UV irradiance during the course of the 11-year solar cycle.

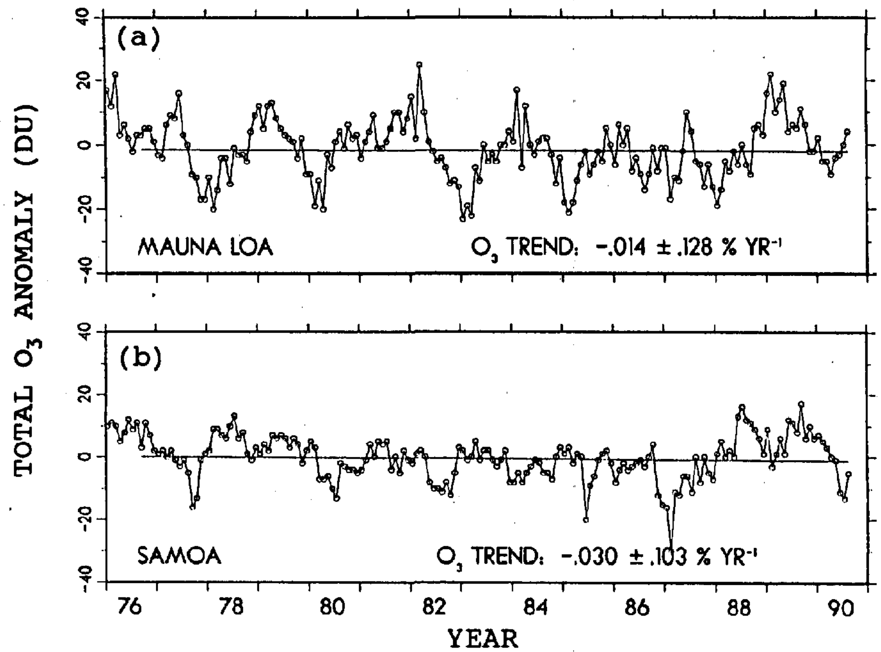


Figure I-9. Monthly mean total ozone anomaly in Dobson units (DU) vs. year (1976-August 1990) for Mauna Loa and Samoa. One DU=10^{-3} cm of ozone at standard temperature and atmospheric pressure. (Courtesy Walter D. Komhyr, Climate Monitoring and Diagnostics Laboratory, NOAA Office of Oceanic and Atmospheric Research)

c. Methane

The radiative properties and abundance of atmospheric methane (CH_4) makes it the most important greenhouse gas next to CO_2 and water vapor. Its photochemical oxidation in the atmosphere can lead to ozone production and ultimately leads to formation of CO_2 and water, adding indirectly to the greenhouse effect. Methane is produced by thermogenic and microbial processes. Thermogenic methane is released during the extraction and refining of oil, coal mining, and the production and transmission of natural gas. Microbial methane is produced by bacteria in oxygen deficient environments, and its sources include swamps, bogs, rice paddies, and the digestive tracts of cattle and termites. Other methane sources include biomass burning and degradation of organic material in landfills. The atmospheric residence time for methane is approximately 10 years.

The NOAA/CMDL monitors the global distribution of methane. Samples are collected weekly at about 30 sites distributed from 82°N to the South Pole. Figure I-10 shows global monthly mean methane mixing ratios in parts per billion (ppb = parts in 10^9) determined from the data set for the period 1983-1990. The mean increase in methane averaged over this time period is approximately 11.5 ppb/year.

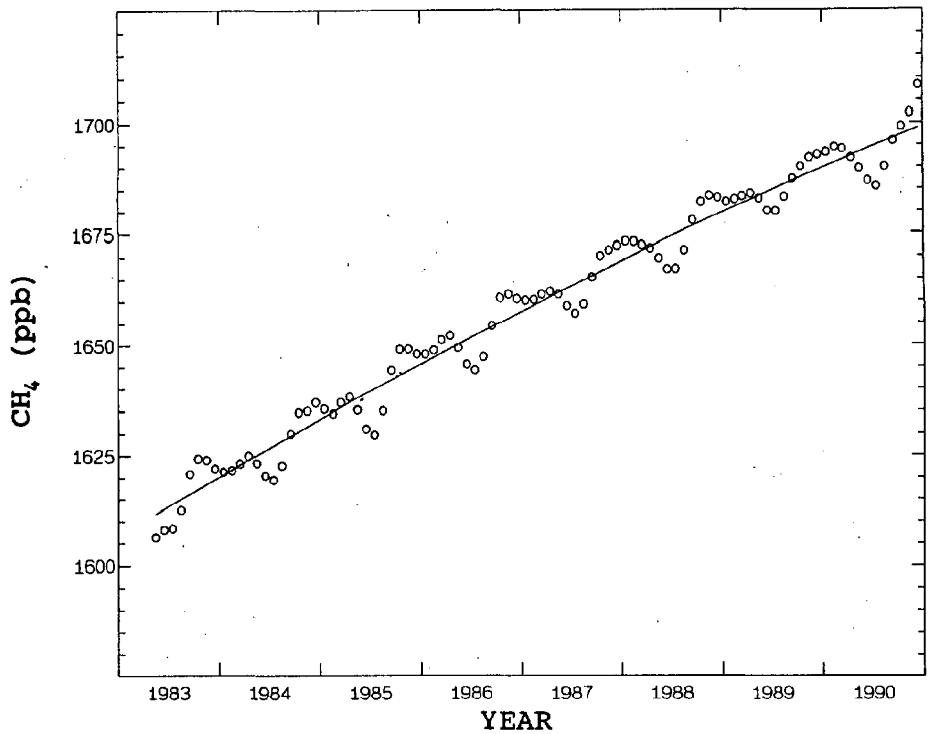


Figure I-10. Global monthly mean values of methane in parts per billion (ppb) for 1983-1990. (Courtesy Edward Dlugokencky, Climate Monitoring and Diagnostics Laboratory, NOAA Office of Oceanic and Atmospheric Research)

HYDROLOGICAL CYCLE

The hydrological cycle has a major influence on the global climate system. It is responsible for much of the vertical energy exchange from the Earth's surface to the atmosphere and the transfer of heat from the tropics to the poles. In addition, the presence of water vapor in the atmosphere and condensed water in the form of clouds has a strong influence on the Earth's radiation budget. The availability of water determines regional climate, vegetation, and the rate of geological weathering, and strongly influences the biogeochemical cycle.

a. Precipitation

Precipitation is one aspect of the hydrological cycle that is regularly monitored. It is vital to agriculture and a critical factor in water resource planning. Precipitation is defined as all forms of water which fall to the ground such as rain, sleet, snow, hail, and drizzle. Since global-scale precipitation patterns are influenced by large-scale climate changes, they are an important indicator of climate variability. Large-scale precipitation patterns are affected by feedback between surface characteristics (albedo, vegetative cover, and soil moisture), atmospheric circulation, and evaporation over the oceans.

i. Global

Compared to temperature, global precipitation has proven much more difficult to observe and characterize. In part, this is because precipitation has a more complicated spatial and temporal structure. Large regions of the globe experience a pronounced temporal cycle of precipitation, with the majority of the precipitation falling over part of the year and very little falling during the remainder of the year. There is also a tendency to fail to report precipitation during the dry season.

Analysis of annual precipitation for the decade 1981-1990 indicates that during this period it was wetter than normal over much of North America and northern Europe, while southern Europe and extreme eastern and southeastern Asia tended to be drier than normal. Large areas received no analysis due to the lack of complete data at a substantial number of stations. There were not enough data to support annual analyses over northern South America, most of Africa, and large portions of Asia.

In Figure I-11, annual global precipitation variability is characterized through the use of a statistical index. In this index, precipitation at each station over the past 40 years is ranked and then transformed into a percentile more or less than normal. The median values of the global annual precipitation index for the 1980s suggest that this decade was more variable than earlier decades in the record. The wettest year on record was 1983 when precipitation for half of the areas ranked in the 75th percentile or greater. Furthermore, 10 percent of the areas experienced their wettest year in the 40-year record. Conversely, 1988 was one of the driest years in the record having the lowest median index in the series.

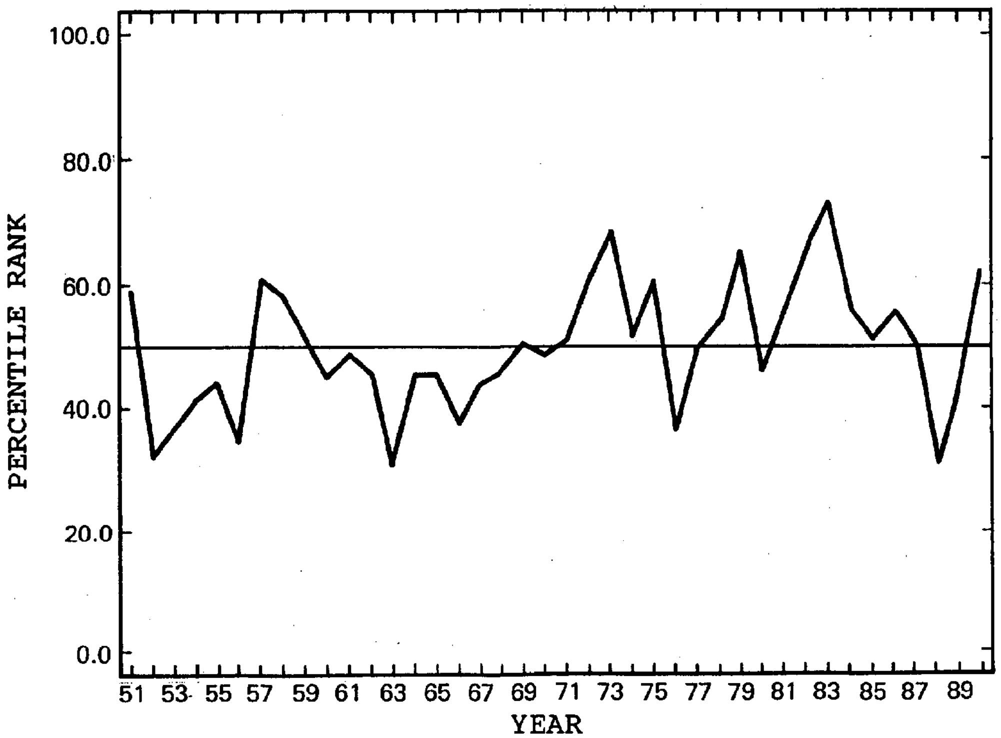


Figure I-11. Time series of the global annual precipitation index. The solid line gives the median value of the percentile rank for precipitation. The index is based on station precipitation in 2° latitude by 2° longitude grids. The median value of this index gives the percentile rank observed in half of the observational grids. (Courtesy Climate Analysis Center, NOAA National Weather Service)

ii. Regional

On a regional scale, the precipitation index for Europe (Figure I-12) suggests that precipitation during the 1980s was characterized by large interannual variability.

For Africa, abnormally dry conditions in the Sahel intensified throughout the decade of the 1980s (Figure I-13a). An index based on data for 20 stations distributed throughout the western Sahel was used to monitor rainfall for the June through September period. Rainfall during these months accounts for over 90 percent of the regions yearly precipitation. Data indicate a decrease during the early part of the decade, with the driest seasons occurring during 1983 and 1984. Towards the end of the decade, seasonal precipitation totals increased. 1988 and 1989 marked the first time since the 1960s that the Sahel had received near normal rainfall in two consecutive years. Precipitation for the decade, however, ended on a poor note as amounts were well below normal during 1990.

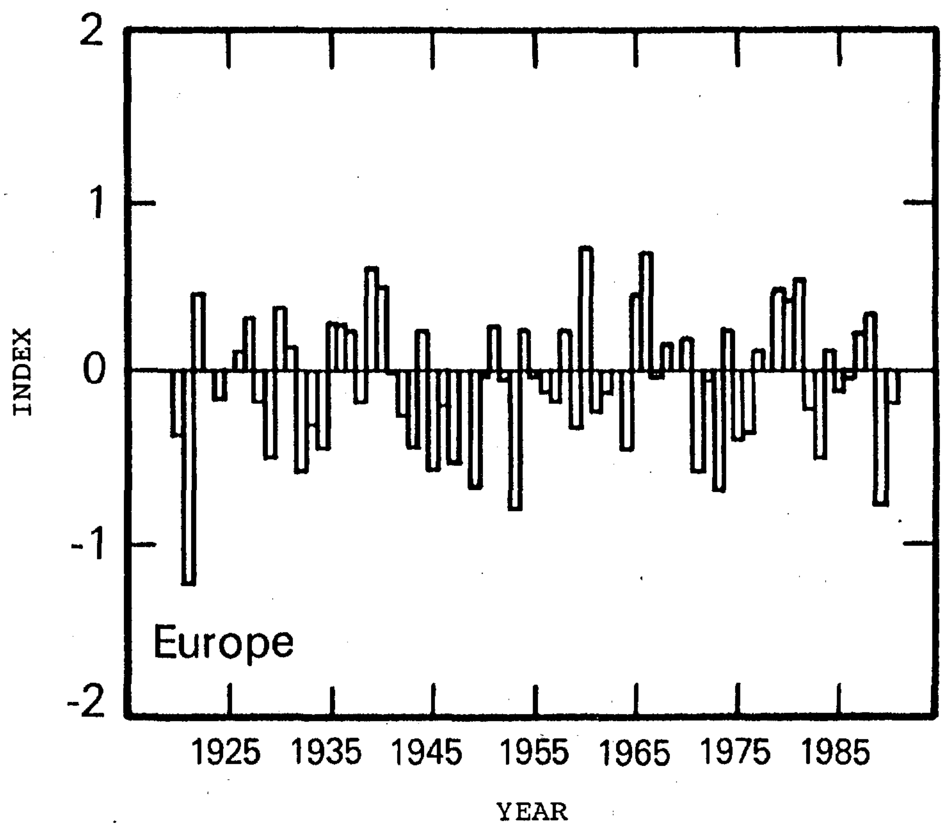


Figure I-12. Precipitation index (average percentiles of station precipitation within the region) for Europe, 1922-1990. (Courtesy Climate Analysis Center, NOAA National Weather Service)

Precipitation indices for two other regions, northern Australia (Figure I-13b) and southeastern Asia (Figure I-13d) also show dry conditions for most of the decade. The northern Australia time series for the summer (November through April) shows positive precipitation index values for 1981, 1982, and 1989. It is interesting to note that during the 1980s, both the Sahel region and southeastern Asia consistently showed strong negative precipitation index values while the Indian summer monsoon showed much more year-to-year variability (Figure I-13c). In fact, according to this index, India experienced one of its worst droughts, associated with the 1986-87 ENSO, followed by one of its wettest years, associated with the 1988 Southern Oscillation episode.

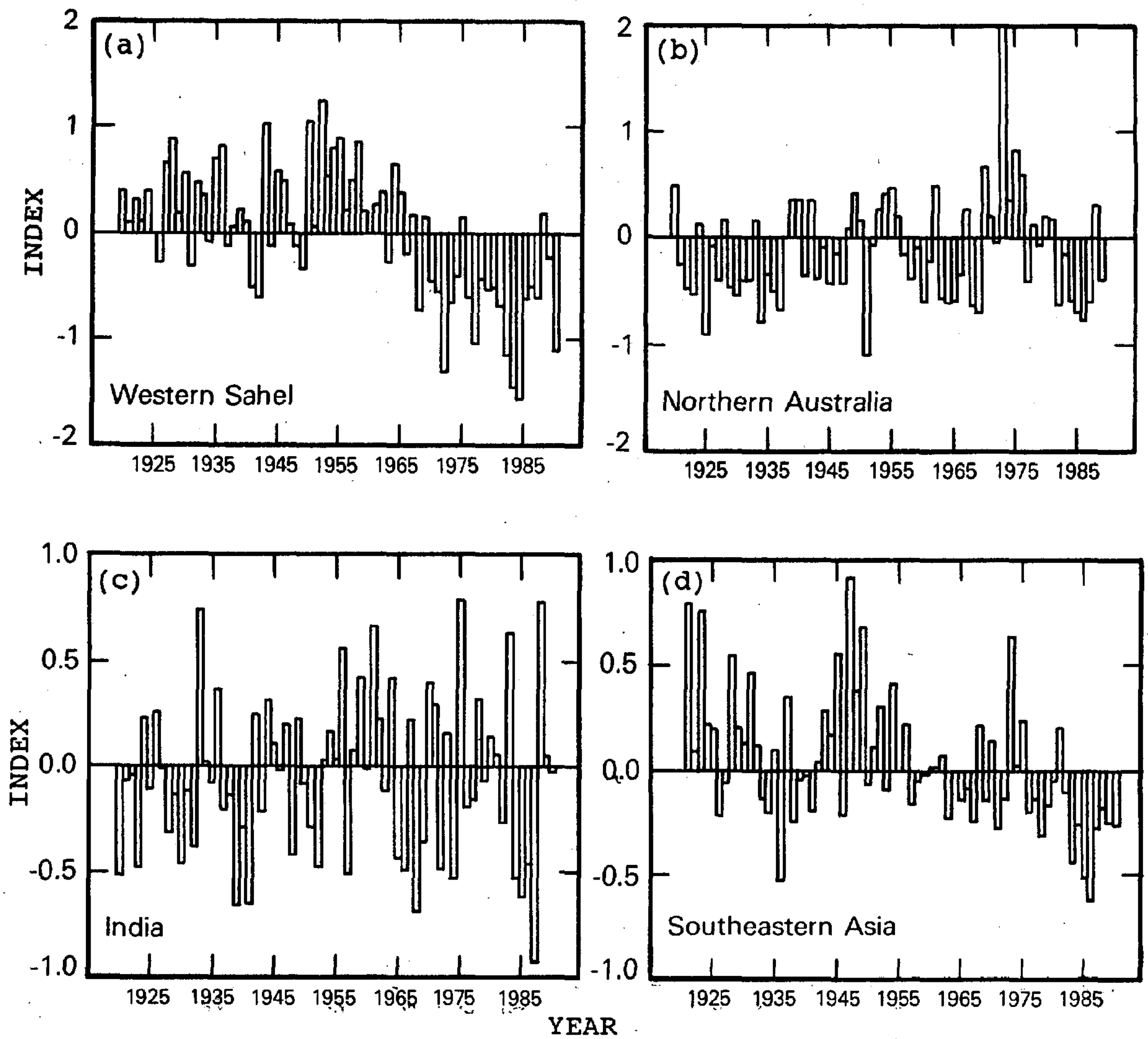


Figure I-13 (a)-(d). Precipitation index, 1920-1989, for (a) western Sahel, June-September; (b) northern Australia, November-April; (c) India, June-September; and (d) southeastern Asia, April-September. (Courtesy Climate Analysis Center, NOAA National Weather Service)

Looking at the United States as a whole for 1990, areally-averaged precipitation for the nation was above normal, ranking 1990 as the twelfth wettest (85th driest) year. This ends a three-year streak of below-normal years and marks a return to the wetness of the early-to-mid-1980s (Figure I-14).

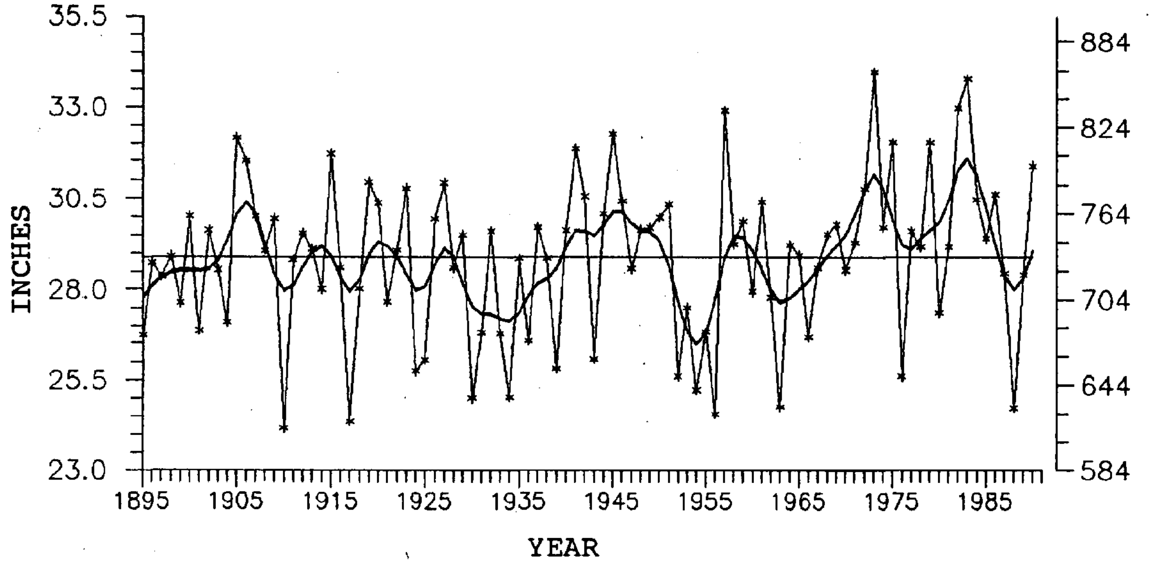


Figure I-14. Areally-weighted annual precipitation in inches and millimeters (mm) for the contiguous United States, 1895-1990. (Courtesy Richard R. Heim Jr., National Climatic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

b. Drought

The Palmer Drought Severity Index (PDSI) is used to measure long-term drought and can be used to measure long-term wet conditions as well. Figure I-15 shows the percent area in the contiguous United States that experienced severe and extreme wet and dry conditions. The PDSI was calculated for each of the 344 climate divisions in the contiguous United States. The percent area of the country in severe-to-extreme long-term drought (PDSI <= -3.00) and severe-to-extreme long-term wet conditions (PDSI >= +3.00) is shown for January 1895-April 1991.

During the 1980s, the United States experienced two periods when more than 25 percent of the country had severe and extreme PDSIs. Neither of these drought episodes affected as much of the country as the decades of the 1930s and the 1950s. However, the wet spell in the middle of the 1980s (Figure I-15b) was the largest of the 20th century. This finding is consistent with the Northern Hemisphere precipitation anomaly analysis for the 1980s which shows excess precipitation in the central United States over the decade.

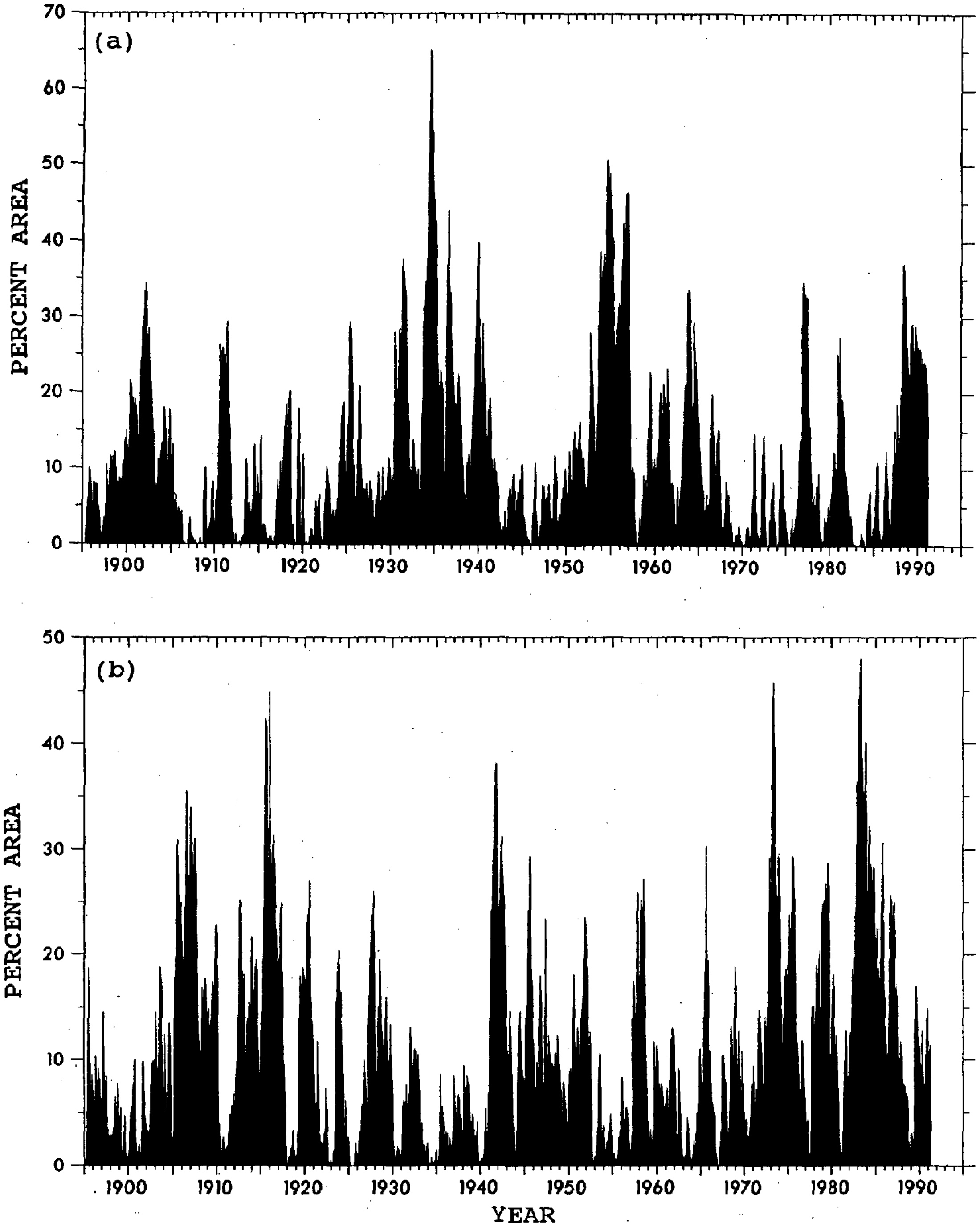


Figure I-15 (a)-(b). Monthly time series of the areal percent of the contiguous United States experiencing severe-to-extreme long-term (a) drought and (b) wet conditions based on calculations of the Palmer Drought Severity Index for January 1895 to April 1991. (Courtesy Richard R. Heim, Jr., National Climatic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

ATMOSPHERIC DEPOSITION

The National Atmospheric Deposition Program was initiated in 1978 to determine the temporal and spatial trends of atmospheric deposition and the effects of deposition on agriculture, forests, rangelands, and freshwater streams and lakes. To accomplish this task, an observation network was established with strict siting criteria and collection protocols. By 1982 the program enjoyed broad federal, state, and industry support, and was partially merged into the National Acid Precipitation Assessment Program National Trends Network. By the late 1980s, the network consisted of approximately 200 stations, about 10 of which were located at NOAA National Weather Service stations evenly distributed across the United States and funded by NOAA's Air Resources Laboratory. Routine measurements for pH, conductivity, precipitation depth, sulfate, nitrate, ammonium, chloride, orthophosphate, sodium, potassium, calcium, and magnesium are made for each weekly precipitation sample. Figure I-16 gives examples of these data showing the temporal variation of sulfate concentration for two sites in Maine and Texas based on a two-year period from April 1984 to July 1986. Weekly samples having no precipitation have been deleted from the illustrations.

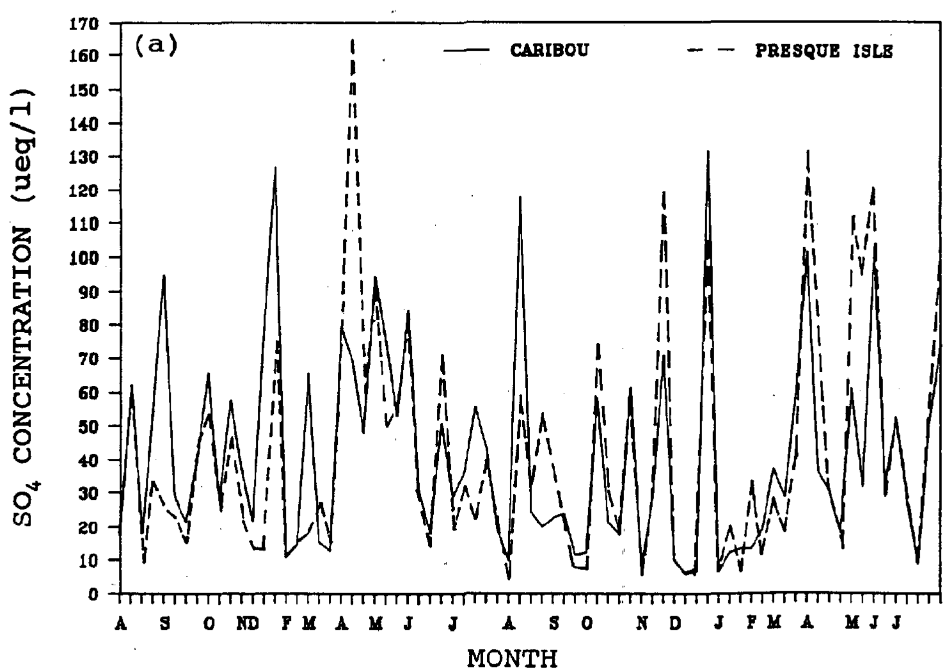


Figure I-16 (a)-(b). Sulfate values for (a) Caribou and Presque Isle, Maine, August 1984-July 1986, and (b) Victoria and Beeville, Texas, April 1984-March 1986 in microequivalents per liter (ueq/l). Periods with no data removed. (Courtesy Richard S. Artz and Glenn D. Rolph, Air Resources Laboratory, NOAA Office of Oceanic and Atmospheric Research)

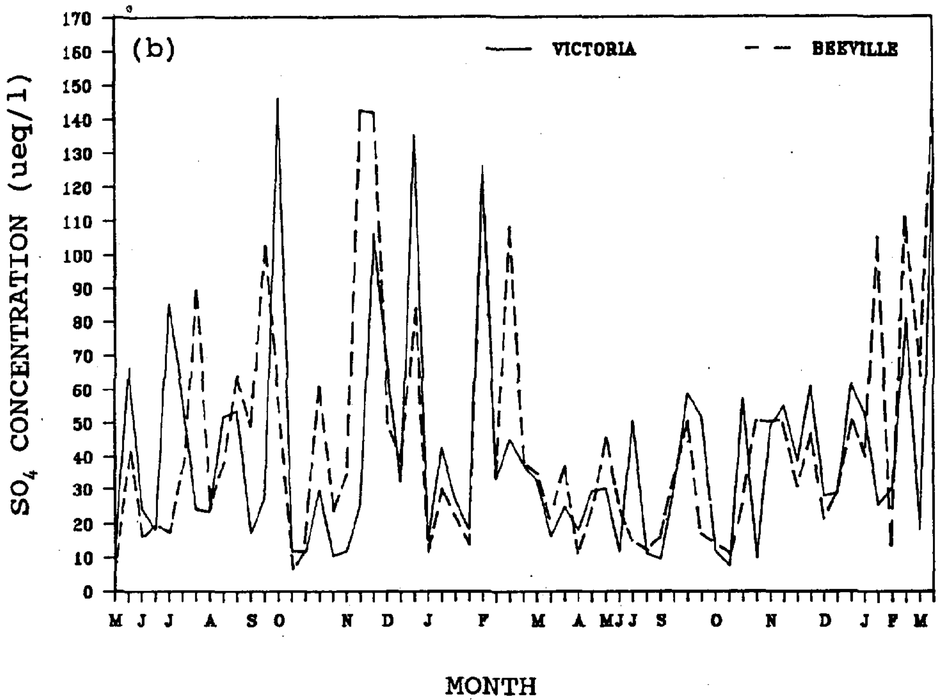


Figure I-16 continued.

SOLAR ACTIVITY

Solar radiation initiates the complex energy transfers that drive the weather and climate system of the Earth. Variations in solar output are inferred from measurements of sunspots, emitted microwave energy, and total solar irradiance. Measurements of total solar irradiance (the "solar constant") indicate that total solar output is constant to within a few tenths of a percent. However, solar emissions from the outer portions of the Sun, represented by sunspots and microwave emissions, are highly variable. The frequency of these emissions is dominated by the 11-year solar cycle. During years corresponding to maxima in the cycle, solar activity such as sunspots, flares, and microwave bursts are numerous, while near times of the minima, solar activity practically disappears. Extremes in solar activity cause detrimental effects to humans and equipment in space and to earth-based communication and electrical power networks.

a. Sunspot Number

Sunspots are dark (cool) areas on the Sun's surface that interrupt the regular pattern of solar emissions. Sunspots are accompanied by strong magnetic fields and have lifetimes ranging from days to a few months. Sunspot frequency rises and falls with the 11-year solar cycle and provides an index of solar magnetic activity.

In 1848 the Swiss astronomer Johann Rudolph Wolf introduced a daily measurement of sunspot number. His method, which is still used today, counts both the total number of spots visible on the face of the Sun and the number of groups into which they cluster because neither quantity alone satisfactorily measures sunspot activity. Results can vary greatly, however, since the measurement strongly depends on observer interpretation and experience and on the stability of the Earth's atmosphere above the observing site. To compensate for these limitations, each daily international number is computed as a weighted average of measurements made from a network of cooperating observatories.

Monthly mean values are shown in Figure I-17. These data also contain a 27-day fluctuation that reflects the rotation period of the Sun. The highest daily counts on record occurred December 24 and 25, 1957. On each of these days the sunspot number totalled 355. In contrast, during years near the minimum of the spot cycle, the count can fall to zero. Today, much more sophisticated measurements of solar activity are made routinely, but none has the link with the past that sunspot numbers have.

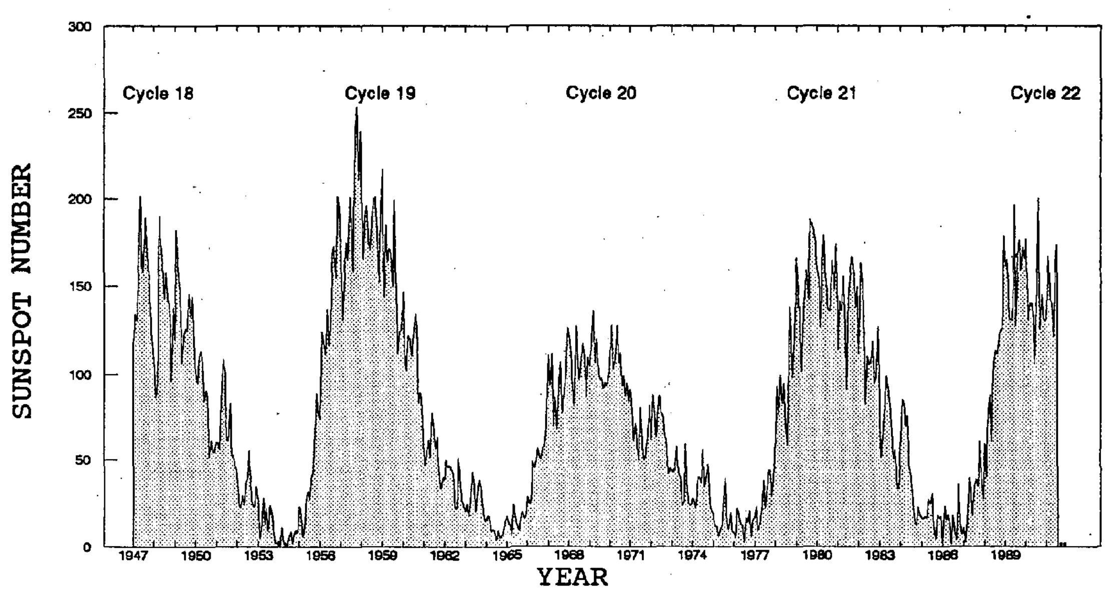


Figure I-17. Monthly mean sunspot numbers, January 1947-July 1991. (Courtesy John A. McKinnon, National Geophysical Data Center, NOAA National Environmental Satellite, Data, and Information Service)

b. Microwave Flux

The Sun emits radio energy with a varying intensity. The brightness of the Sun can be measured by the strength of emission at a wavelength of 10.7 cm (2800 megaHertz). This radio flux, which originates from layers in the Sun's chromosphere and corona, changes in response to the number of sunspots. Microwave flux (at 2800 megaHertz) observations summed over the Sun's disk have been made continuously since February 1947. Observed mean flux variations are shown in Figure I-18.

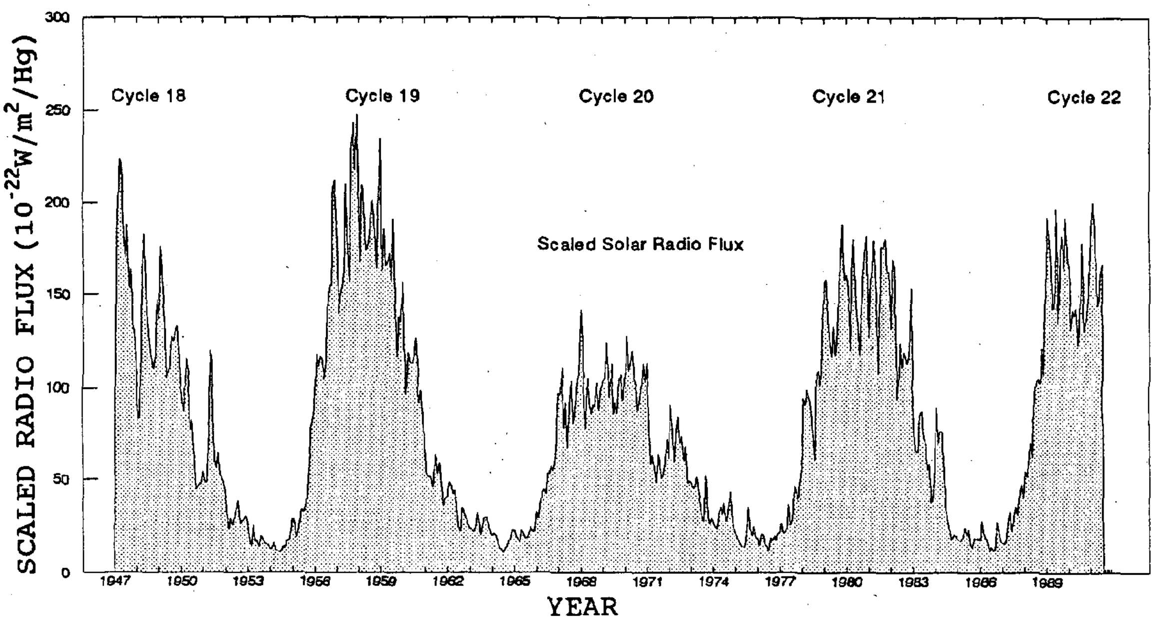


Figure I-18. Monthly mean 2800 megaHertz (MHz) solar microwave flux, January 1947-July 1991. (Courtesy John A. McKinnon, National Geophysical Data Center, NOAA National Environmental Satellite, Data, and Information Service)

c. Total Solar Irradiance

Total solar irradiance describes the radiant energy emitted by the Sun over all wavelengths that falls each second on one square meter at the top of the Earth's atmosphere. This is a quantity proportional to the "solar constant." Total solar irradiance is proportional to the Sun's luminosity, that is, to all the energy per second the Sun emits into space.

Figure I-19 shows short- and long-term irradiance variations, as measured by 5 different satellites. These values reveal day to day changes in response to the number of sunspots on the disk, and they show the Sun dims slightly during sunspot minimum and brightens slightly during sunspot maximum. Brightness changes are small, but a survey of about 100 other stars suggests the Sun's luminosity could potentially vary by several percent. Points connected by a continuous line at the top trace daily measurements from the Nimbus-7 satellite; the next lower profile tracks results from the Solar Maximum Mission (SMM) satellite; and the unconnected symbols at lower right mark infrequent samples from the Earth Radiation Budget Satellite (ERBS), NOAA-9, and NOAA-10 satellites.

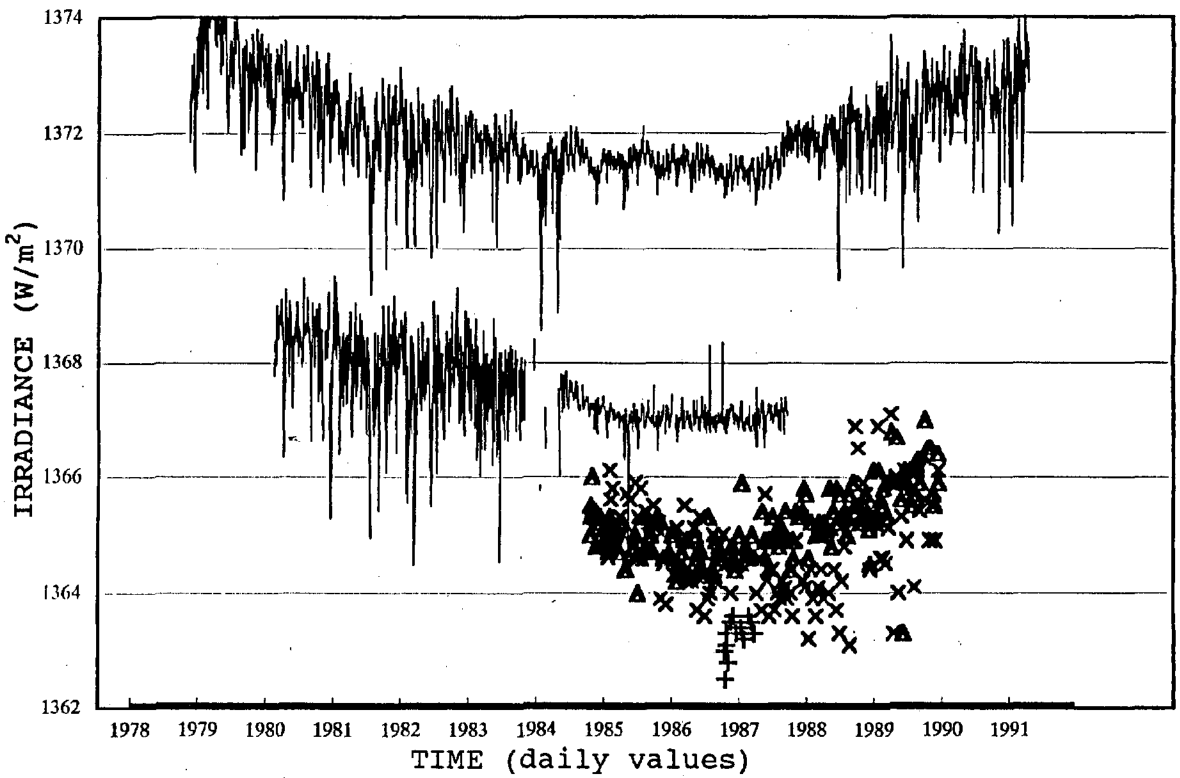


Figure 1-19. Total solar irradiance (watts/square meter): values from (upper line) Nimbus-7, 16 Nov.78-30 Apr.91; (lower line) Solar Maximum Mission (SMM), 16 Feb.80-8 Oct.87; (open triangle) Earth Radiation Budget Satellite (ERBS), 25 Oct.84-20 Dec.89; (x) NOAA-9, 23 Jan.85-20 Dec.89; (+) NOAA-10, 22 Oct.86-1 Apr. 87. (Courtesy John A. McKinnon, National Geophysical Data Center, NOAA National Environmental Satellite, Data, and Information Service)

EARTH'S RADIATION BUDGET

The Earth, atmosphere, and oceans are constantly absorbing solar radiation and emitting radiation to space. Variations in the radiation budget are the driving mechanism for atmospheric and oceanic circulation and the inter-related weather and climate. Over long periods of time the global rates of radiative absorption and emission are very nearly equal.

a. Longwave Flux

Measurements of the global mean outgoing longwave radiation flux are fundamental to the understanding of the Earth's radiation budget. The global monthly mean flux as measured by satellite remote sensing is shown in Figure I-20 for the period from June 1974 through March 1991. The values plotted from 1974 to 1978 were those obtained from the scanning radiometer on NOAA satellites 2,3,4, and 5, while those beginning in 1979 were obtained from the Advanced Very High Resolution Radiometer (AVHRR) on satellites TIROS-N and NOAA-6,7,9, and 11. Clearly depicted is an annual cycle. The variations from cycle to cycle are due to changes in the instruments and satellite paths, in addition to actual changes in longwave flux. The annual means show changes that are less than 3 watts per square meter.

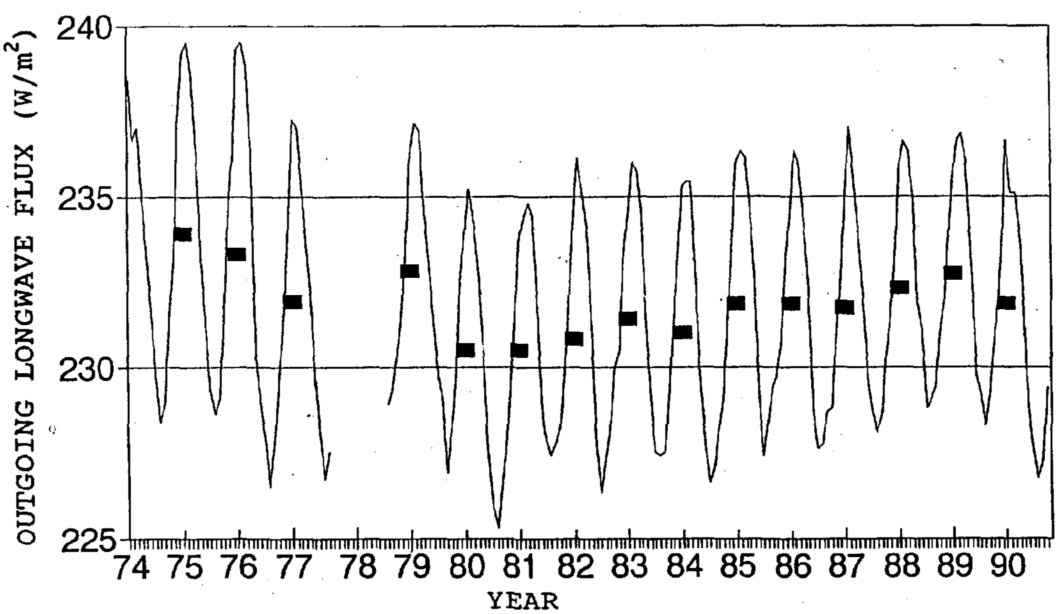


Figure I-20. Global mean longwave flux in watts/square meter, June 1974-March 1991. Dark square indicates annual mean. (Courtesy Herbert Jacobowitz, Satellite Research Laboratory, NOAA National Environmental Satellite, Data, and Information Service)

b. Regional Cloudiness/Sunshine Duration

There is growing interest in measurements of changes in cloudiness mainly because of the associated concern with greenhouse warming. One question that is now being addressed is whether there is a measurable increase in cloudiness as a result of global warming and what influence would this increase have on global temperature change.

An accurate assessment of cloudiness variations on a global scale can be obtained through the use of satellites. It is also useful to examine variations in cloudiness on a regional scale (such as the United States) based on observed station data in order to establish the potential relationships with observed global perturbations like El Nino.

In Figure I-21 the variations in United States cloudiness (percent of sky covered by clouds as estimated by observers at 100 NOAA National Weather Service stations) and the sunshine duration (percent of possible sunshine as estimated by sunshine recorders at these same 100 stations) are examined for the years 1950-1990. During this period, the correlation between annual values of cloudiness and minimum sunshine duration within the contiguous United States was -0.86, significant at the 1 percent level. The years of maximum cloudiness and sunshine duration were 1972 and 1982 (both during times of the start of a strong El Nino). The year of maximum sunshine duration was a drought year (1988). Despite the low value of cloudiness in 1988, cloudiness increased by 3.5 percent between the first half and the last half of the record.

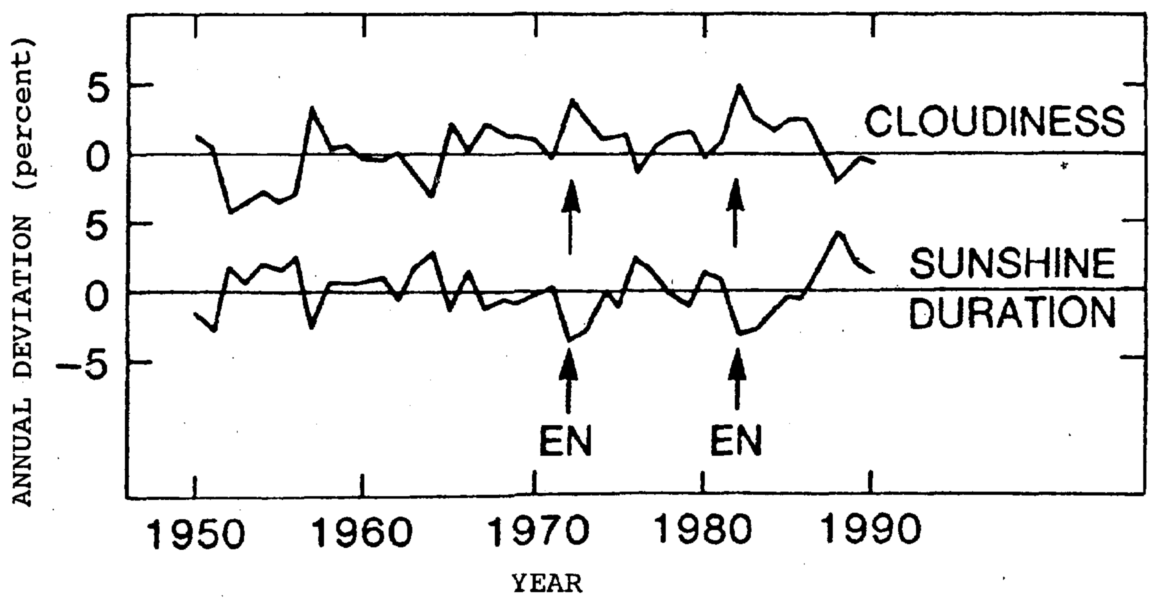


Figure I-21. Variation in U.S. cloudiness and sunshine duration (1950-1990) expressed as annual percent deviations from the mean cloudiness (58 percent) and sunshine duration (63 percent) for this period. Relatively low values from 1952-1956 reflect drought occurring during this period. Arrows indicate beginnings of major El Nino (EN) events. (Courtesy James K. Angell, Air Resources Laboratory, NOAA Office of Oceanic and Atmospheric Research)

c. Radiation Budget-Arabian Gulf Region

The planetary albedo and outgoing longwave radiation flux were analyzed for the Arabian Gulf (Persian Gulf) region for the period starting before and during the massive oil fires to provide a quantitative measure of their affect on the regional climate. Figure I-22 shows the variation for an area in Saudi Arabia, where the smoke from the oil burning was very intense. The lowering of the normal clear-sky albedo by up to 15 percent due to the presence of smoke is evident. The absorption by the smoke of the solar radiation that would normally have penetrated to the ground led to a dramatic cooling at the surface. The albedo has returned to normal levels about the time the last fire was extinguished.

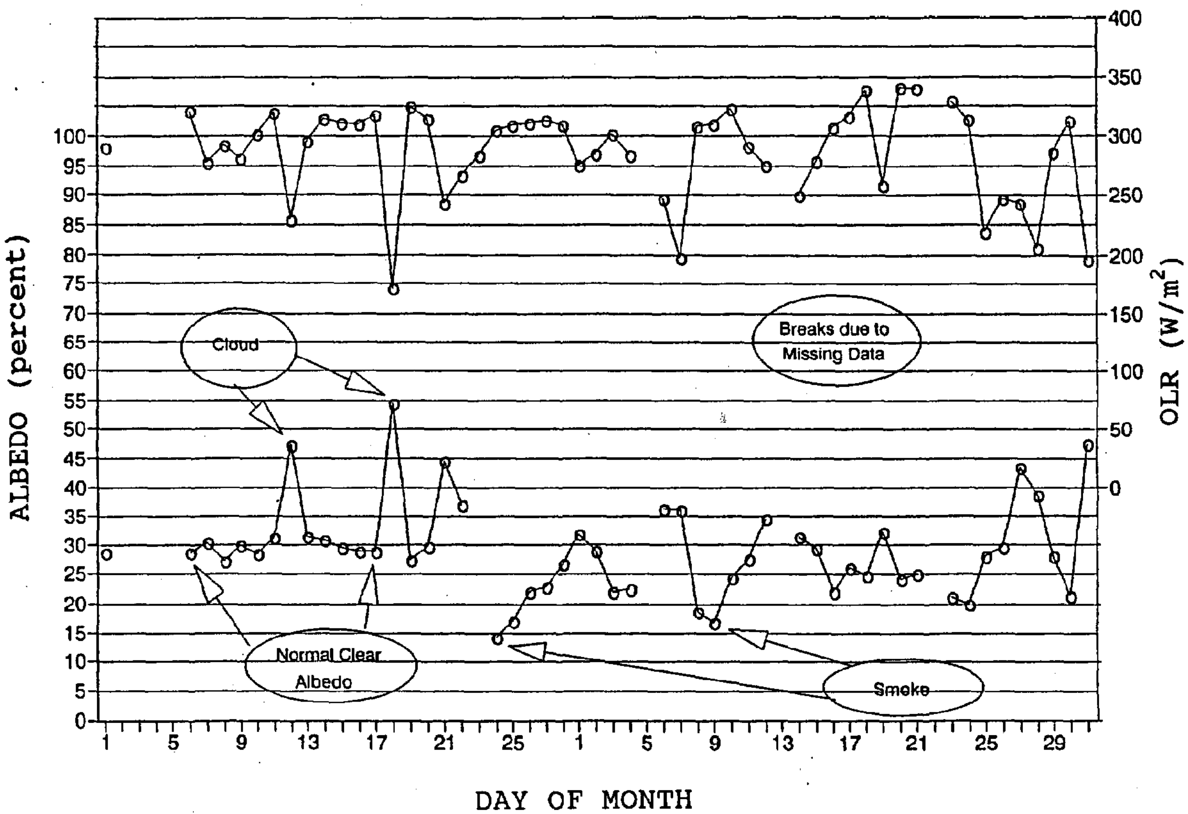


Figure I-22. Relationship between percent albedo (lower graph) and outgoing longwave radiation (OLR) in watts/m² (upper graph) from an area in Saudi Arabia (22.5°N, 55°E) affected by the oil fires in Kuwait, February-March 1991. Data from AVHRR on NOAA-11 satellite (2.5° latitude/longitude average resolution). (Courtesy Herbert Jacobowitz, Satellite Research Laboratory, NOAA National Environmental Satellite, Data, and Information Service)

SEVERE WEATHER

Much of the weather that causes loss of life and disrupts economic activity is related to mesoscale phenomena. Severe weather includes tornadoes, squall lines and thunderstorms, hail storms, flash floods, and heavy snows. Larger-scale severe weather phenomena, such as tropical and extra-tropical storms, are also included in severe weather. Major variations in meso- and large-scale severe weather phenomena may be useful indicators of regional and even global climate change.

a. Tropical Cyclones

Tropical cyclone frequency can be used as a indicator of variability in tropical ocean-atmosphere energy exchange. Since warm sea surface temperatures are required for tropical cyclone formation (i.e., >~27°C), there could be a link between numbers of and severity of tropical cyclones and warming of the tropical ocean.

The annual number of hurricanes and tropical storms in the north Atlantic Ocean for 1886-1990 is shown in Figure I-23. It should be noted that observation methods and coverage have changed during the period. The number during the 1980s was near the long-term mean. However, two of the most devastating north Atlantic hurricanes on record occurred in the late 1980s: Hurricane Gilbert (1988) and Hurricane Hugo (1989).

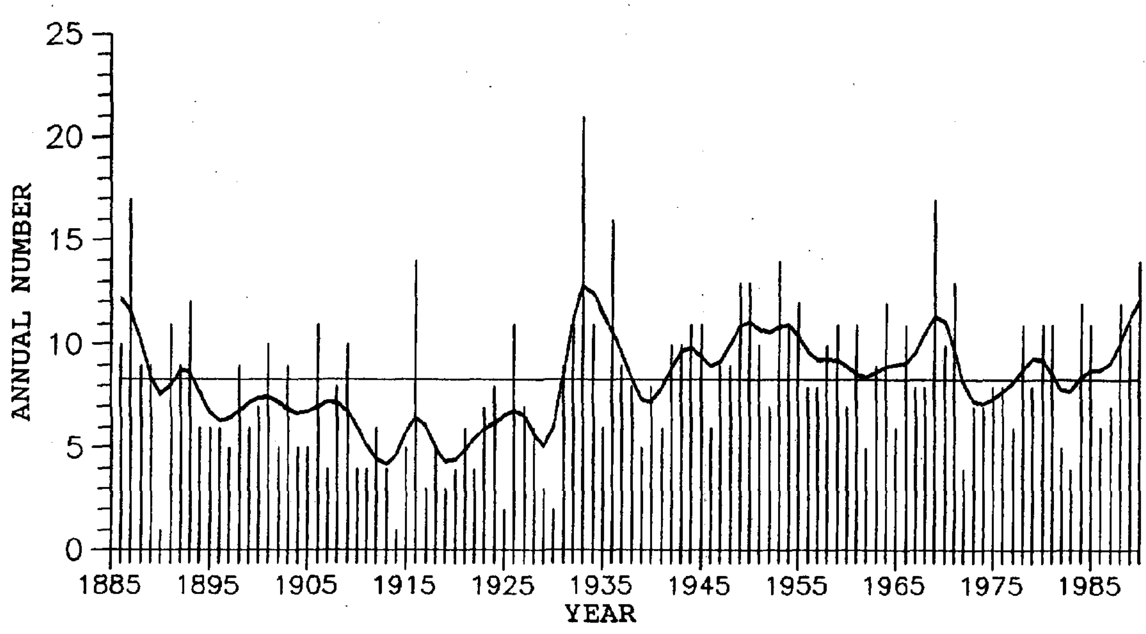


Figure I-23. Annual number of hurricanes and tropical storms, north Atlantic Ocean, 1886-1990. (Courtesy Richard R. Heim, Jr., National Climatic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

b. Tornadoes

Tornadoes are intense local circulation systems with high wind speeds and great destructive force over the narrow path of their movement. Tornadoes are especially frequent over the central portion of the United States. Figure I-24 shows the modern historical record of reported occurrences of tornadoes.

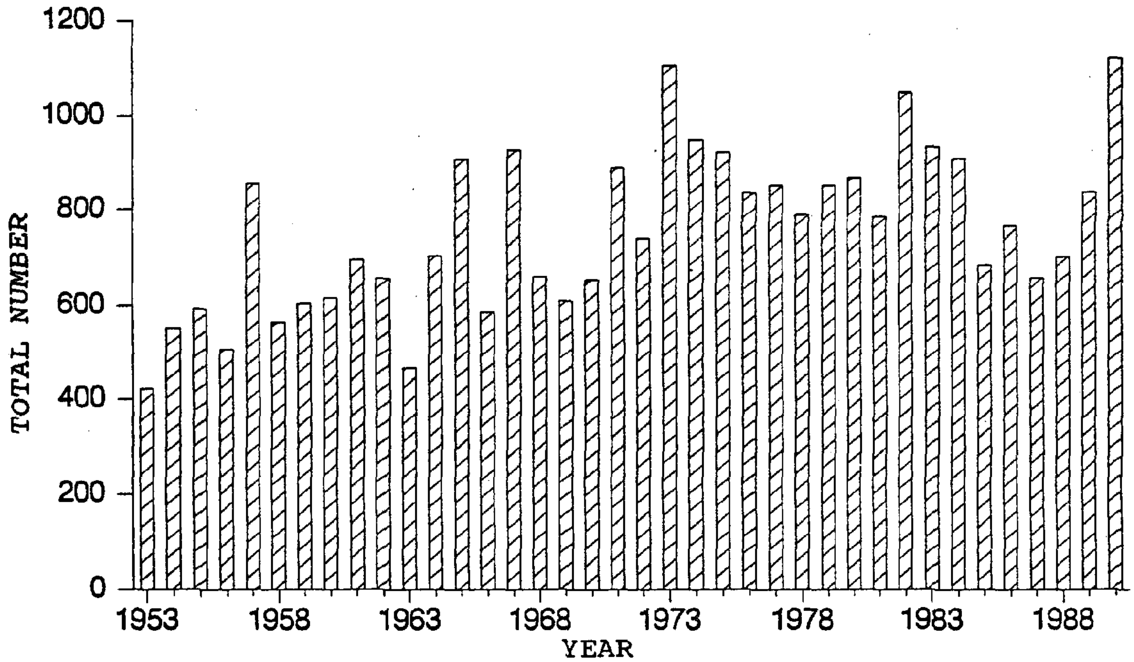


Figure I-24. Total number of tornadoes, 1953-1990. (Courtesy Richard R. Heim, Jr., National Climatic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

c. Winter Storms

Episodes of heavy snowfall, combined with the effects of high winds, and cold temperatures can be particularly debilitating, especially in heavily populated and highly industrialized regions. Such is the case in the northeast United States. Here, heavy snowfall associated with winter storms may maroon millions of people at home, work, or in transit, severely disrupt commerce, and endanger lives. During the years from 1955 through 1985, a number of winter storms resulted in serious impacts to the northeast. The blizzards of February 1958 and January 1966, the triple snowstorms of the 1960-1961 winter, the great New England wind and snowstorm of February 1978, the "Presidents Day Storm" of February 1979, and the paralyzing storm of February 1983 are the most notable events of this period.

i. Mean Seasonal Snowfall

The mean distribution of seasonal snowfall over the northeast United States is largely dependent upon latitude (Figure I-25), ranging from 15 centimeters in the southeastern corner of Virginia to greater than 250 centimeters across sections of central and northern New England, New York, and West Virginia. The primary source of snowfall in this region is extratropical cyclonic weather systems. Areas adjacent to the Great Lakes and the highlands of West Virginia, western Pennsylvania, and Maryland, however, also receive significant snowfall from the passage of cold continental air over the relatively warm moisture-laden air over the Great Lakes in concert with orographic effects.

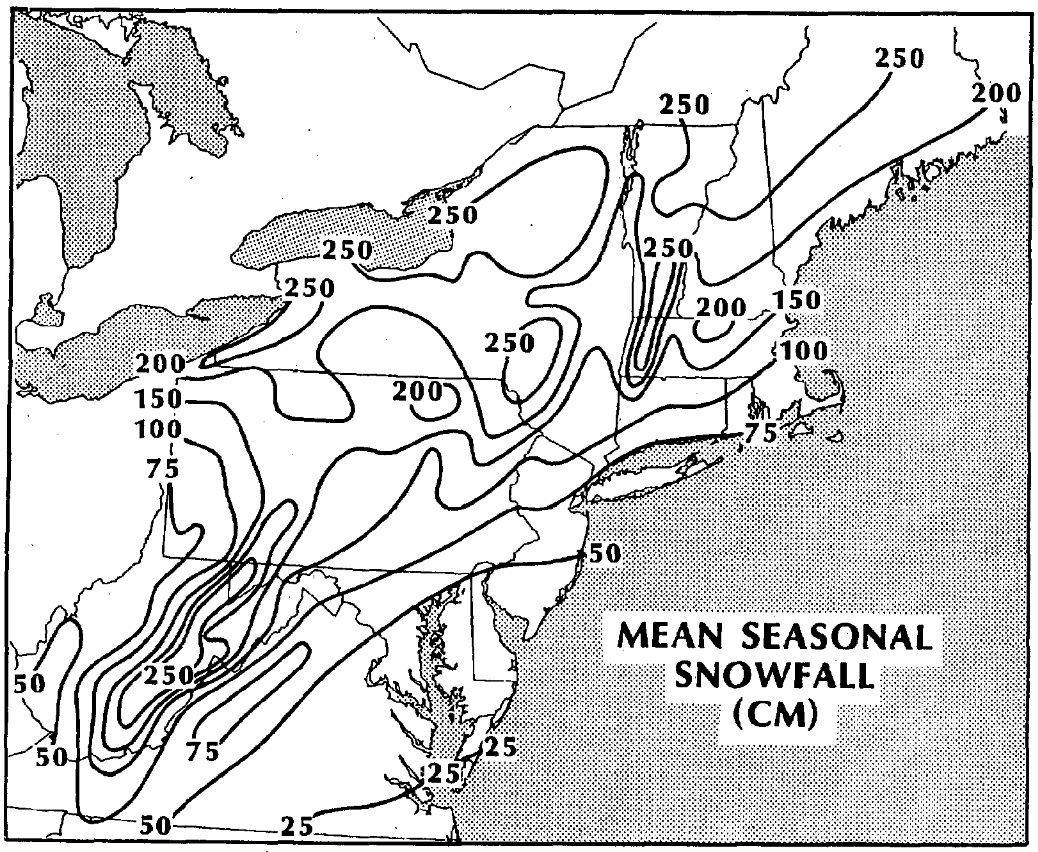


Figure I-25. Mean seasonal snowfall, October through May in centimeters (cm), for the northeastern United States, 1955/56-1984/85. (Courtesy Paul J. Kocin and Louis W. Uccellini, National Meteorological Center, NOAA National Weather Service)

ii. Heavy Snow Occurrences

The number of storms that have produced snow exceeding 10 centimeters (cm) during the 30-year period from 1955-1956 through 1984-1985 ranges from 29 in southeastern Virginia (an average of 1 per winter season), to more than 200 in sections of central New England (an average of 7 events per season).

Storms that deposit 25 cm or more are relatively rare. Only three such storms occurred over the 30-year period in southeastern Virginia, an average of one every 10 years, with 5 to 11 events over the coastal regions from Virginia to southern New Jersey, approximately one every 3 to 5 years. The heavily populated urban corridor from northern Virginia through extreme southern New England experienced 11 to 18 major snowfalls, approximately one every other year. The inland areas of northeastern Pennsylvania, eastern New York, and southern New England received 19 to 33 heavy snows, approximately one every 1 to 2 years, while 34 to 41 events were noted across the northern limits of the area, slightly greater than one per year.

The distribution of moderate and heavy snow events from 1955-1956 through 1984-1985 in each of the five major cities that span the populous coastal region of the northeast are summarized in Figure I-26. Both monthly and 30-year totals are presented for Boston, New York City, Philadelphia, Baltimore, and Washington, DC. During the 30-year sampling period, the total number of events that yielded greater than a 10 cm accumulation ranges from 48 cm at Washington, DC, to 65 cm in New York City, and 100 cm in Boston. January and February account for the majority of these occurrences in Washington, Baltimore, Philadelphia, and New York, while Boston has a distinct maximum in January and a secondary peak in March. The months of December, January, February, and March account for nearly all of the events for each city.

The total number of events that produced at least 25 cm accumulation ranges from 8 at Washington, DC, to 25 at Boston (Figure I-26). February displays the greatest frequency of heavy snow events in every city except Boston, where January has the largest number of heavy snowfalls. The frequency of 10- and 25 cm snow accumulations exhibit only small variations among Washington, Baltimore, Philadelphia, and New York City. Washington recorded marginally fewer events and New York slightly more than the other cities. In contrast, Boston had a 50-100 percent greater incidence of 10 cm snows and two to three times the number of 25 cm events than the other cities. Such a substantial difference indicates that Boston has a significantly greater potential for heavy snowstorms than any of the other cities.

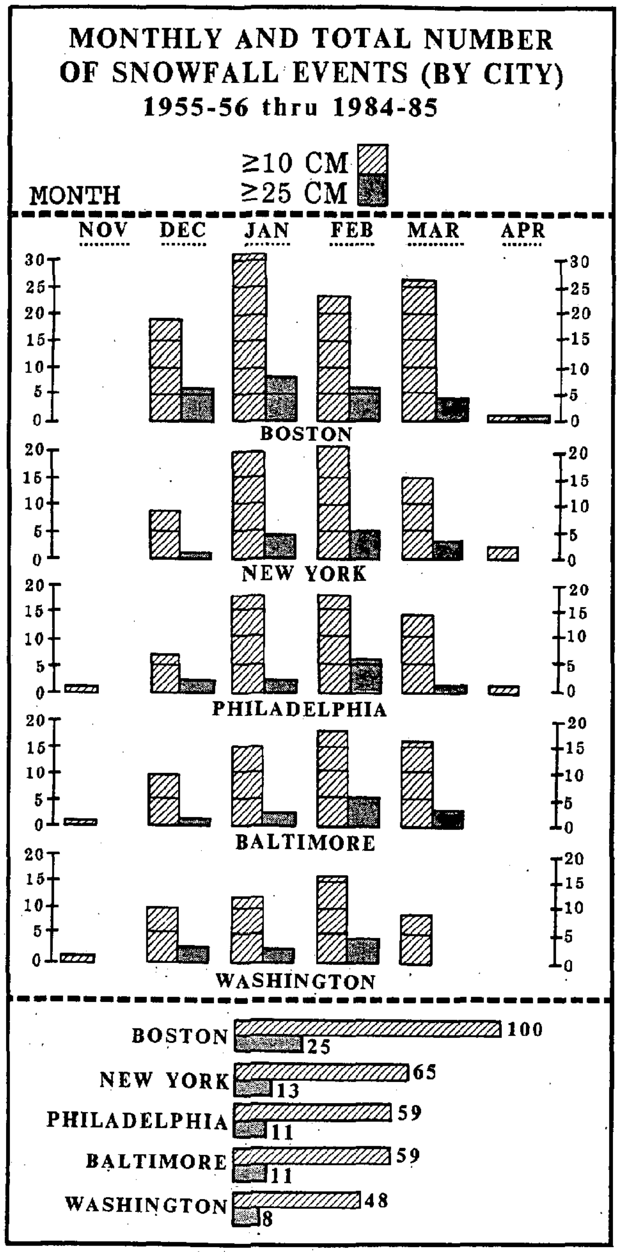


Figure I-26. Monthly and total number of snowfall events (by city) for the winter seasons 1955-1956 through 1984-1985 in Boston, MA; New York, NY; Philadelphia, PA; Baltimore, MD; and Washington, DC. Hatched shading represents the number of events exceeding 10 centimeters (cm) and dark shading represents the number of events exceeding 25 cm. For cities with more than one snowfall measurement, an average value is used to designate events. (Courtesy Paul J. Kocin and Louis W. Uccellini, National Meteorological Center, NOAA National Weather Service)

QUASI-BIENNIAL OSCILLATION

A quasi-biennial oscillation (QBO) of mean zonal winds in the equatorial stratosphere is one classically observed periodic oscillation in the climate system. The QBO, so called because it repeats every 2 to 2.5 years, has been observed since 1950.

The QBO shown in Figure I-27 is based on observations taken at Balboa (Canal Zone), Singapore, and Ascension Island. Recent studies have indicated a statistical relationship between the QBO and surface temperature anomalies and also for activity during the tropical cyclone season. The QBO has been recognized for more than 30 years as having its largest amplitude over the tropics in the atmosphere at 30 millibars, but a QBO signal has been detected in other meteorological and oceanographic parameters.

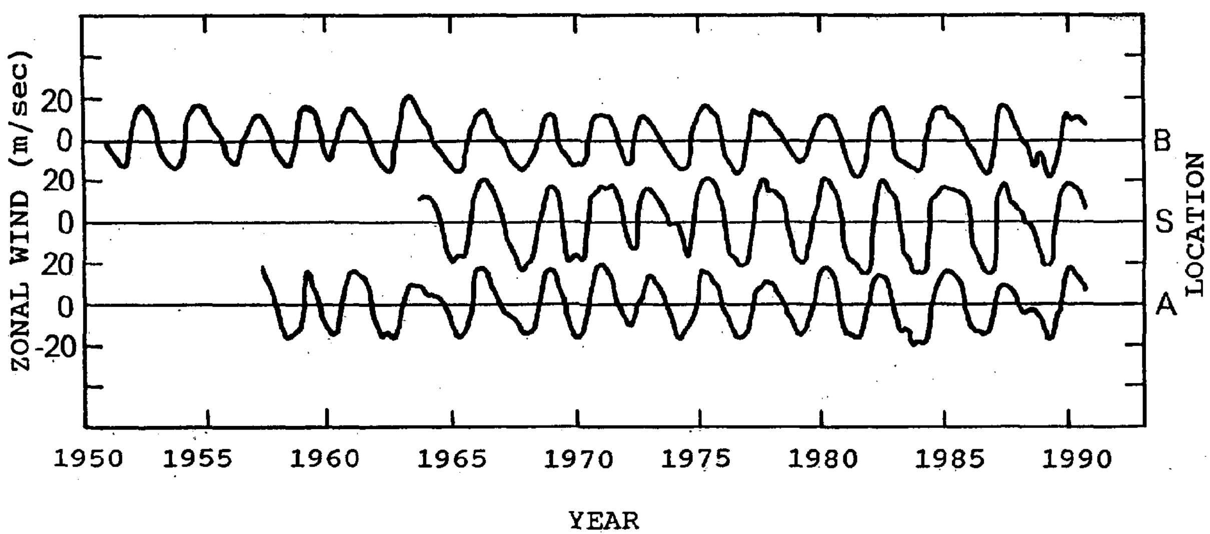


Figure I-27. Variation of the zonal wind (west wind positive) in meters per second (m/sec) at Balboa (B), Singapore (S), and Ascension Island (A) at 30 millibars, based on a 1-2-1 weighting of successive monthly deviations from long-term monthly means. Abscissa tick marks indicate July of the given year. (Courtesy James K. Angell, Air Resources Laboratory, NOAA Office of Oceanic and Atmospheric Research)

SOUTHERN OSCILLATION

The Southern Oscillation (SO) represents a fluctuation of inter-tropical atmospheric circulation, particularly noticeable in observations taken in the Indian and Pacific Oceans. Time series of sea-level pressure, air temperature, sea surface temperature, precipitation, and of sea level from a wide variety of locations have been found to be well correlated with the SO. In particular, the SO has been found to be strongly linked to the El Nino phenomenon, an episodic warming of the tropical Pacific Ocean. This strong correlation is known as the El Nino/Southern Oscillation (ENSO).

The most commonly used measure of the SO is the difference in barometric pressure between Tahiti and Darwin, Australia. This indicator, known as the Southern Oscillation Index, is shown in Figure I-28. With the index, large negative values correspond to warm events and large positive values to cold events. The decade of the 1980s featured one of the strongest ENSO episodes (1982-83) of the last century, one of the strongest cold episodes (1988-89) during the last 50 years, and a major central Pacific warm episode (1986-87). These three events were accompanied by global circulation and precipitation anomalies, which in some cases reached extreme proportions. For example, the ENSO of 1982-83 brought unprecedented wind, wave, and water damage to coastal property along the west coast of the United States. These same storms led to record snowpacks on the Rocky Mountains and also record springtime flooding there.

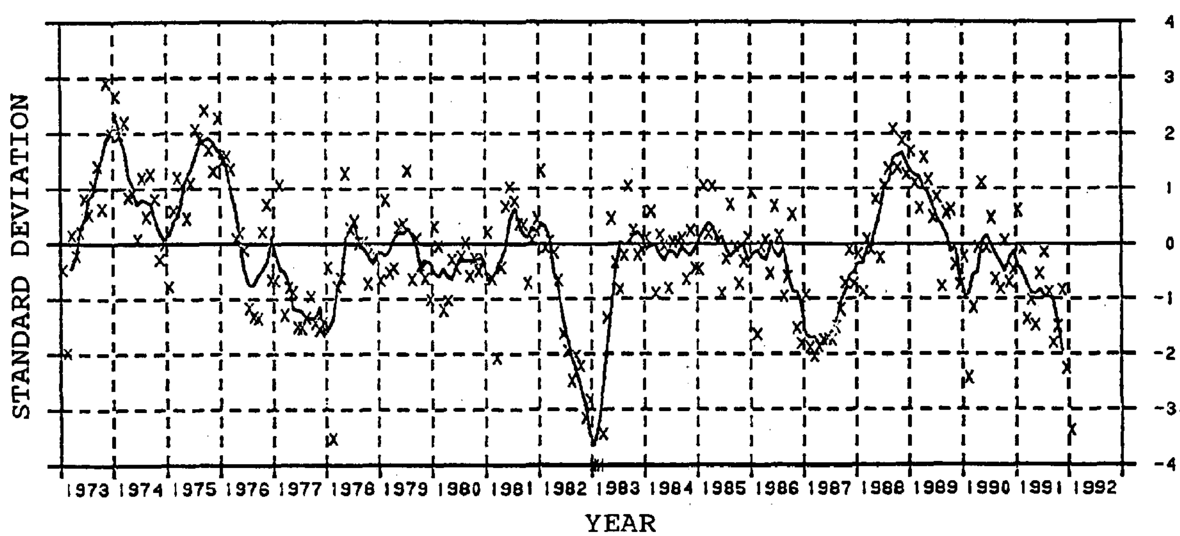


Figure I-28. Five-month running mean of the difference between the standardized barometric pressure anomalies at sea level at Tahiti and Darwin, Australia. Values are standardized by the mean annual deviation. Individual monthly means are marked by an "X". (Courtesy Climate Analysis Center, NOAA National Weather Service)

II. OCEAN

The ocean has a significant influence on climate as the Earth's storehouse of about 97 percent of its water and enormous amounts of heat. Ocean water is 800 times more dense, has 270 times the mass, and has a heat capacity of 4 times that of the atmosphere. These properties impart to the ocean a greater stability than the atmosphere and greater heat storage capacity than both the atmosphere and the surface of the land. Because of these properties, the ocean acts as a buffer, smoothing short-term climate variations and delaying those of longer term. Additionally, the ocean is a major sink in the global carbon cycle and hence a main repository of carbon dioxide, important in controlling the long-term concentration of atmospheric carbon dioxide.

OCEAN TEMPERATURE

Ocean temperature is an important environmental indicator because of the relationship between sea temperature and ocean-atmosphere exchanges of heat, gases, and moisture. In addition, it is useful in identifying and tracking oceanographic features such as fronts, western boundary currents, and mesoscale eddies. Knowledge of seawater temperature in general is necessary (along with salinity and pressure) to determine the density of seawater, important in ascertaining ocean circulation and the mixing capabilities of water masses. An accurate description of sea surface temperature, especially over the oceans, is required for input to weather forecasting models and for computing global heat and moisture fluxes. The long-term trend of global mean sea temperature is an indicator of climate change.

a. Sea Surface

Sea surface temperature (SST) observations have been recorded since the mid-nineteenth century, primarily from merchant ships. SST measurements have traditionally been made using a bucket and thermometer. This method has been replaced by "injection temperatures" (the temperature of sea water as measured at the ship's seawater intake). Because a ship's intake is commonly located below the surface and because the temperature may be influenced by the heat of engines or boilers, injection temperatures have not been considered as reliable as bucket temperatures for SST determination.

SST has been monitored by NOAA polar orbiting satellites since 1982 using infrared measurements obtained from the Advanced Very High Resolution Radiometer (AVHRR). Prominent oceanic features appear in these satellite records such as the seasonal and the interannual fluctuations of SST in the eastern tropical Pacific. Warming occurs during February to April which is consistent with the decreased intensity of easterly trade winds, while cooling is associated with increased wind speeds and upwelling. The interannual warming, called the El Nino, is associated with a collapse of the equatorial trade-wind system. Satellite records have documented two El Nino events since 1982, the first during 1982-83 and the second during 1986-87. The 9-year time series of SST at the equator derived from satellite data illustrates the magnitude of the SST oceanic response (Figure II-1) during times of strong upwelling (late 1988) and El Nino events. El Nino events appear to build up over several years and are then followed by an interval of rapid cooling during the following season.

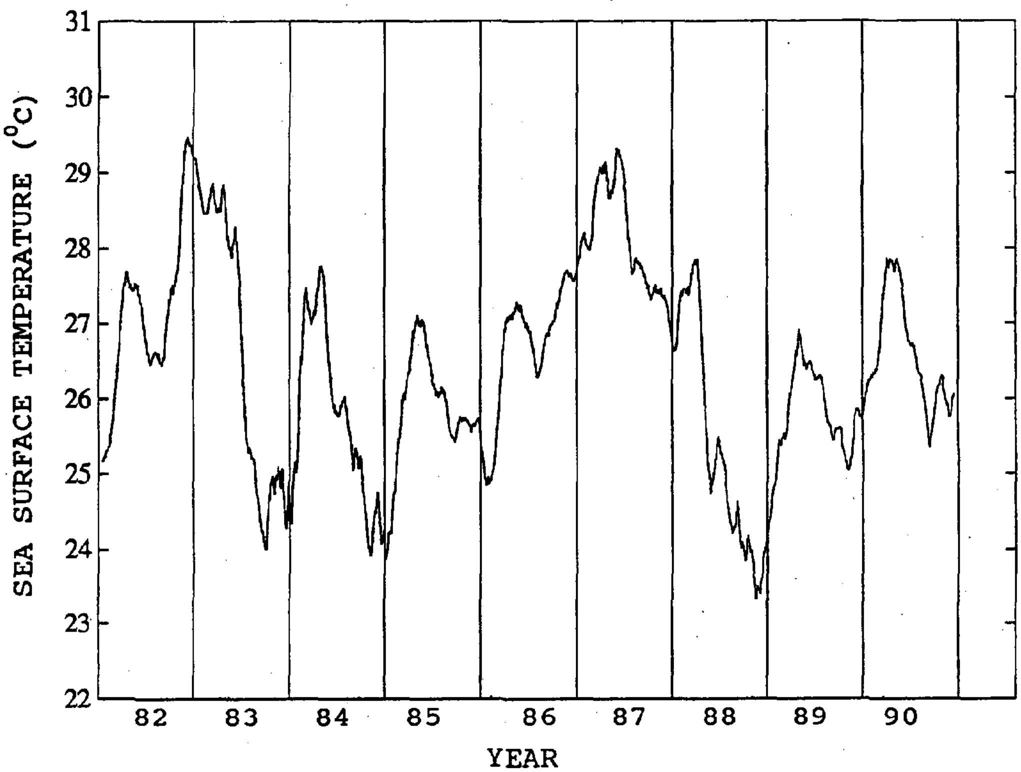


Figure II-1. Sea surface temperature (January 1982-31 December 1990) in the equatorial Pacific (140°W, 02°S) estimated from NOAA satellite infrared measurements. (Courtesy Richard Legeckis, Satellite Research Laboratory, NOAA National Environmental Satellite, Data, and Information Service)

Annual mean SST derived from satellites and in situ buoy and ship SST for the five major ocean basins are shown in Figure II-2. These analyses are from 2.5° latitude/longitude quadrangles of monthly means. While upward tendencies are apparent in both the Pacific and Atlantic Oceans, the Indian Ocean time series departs markedly from the other basins. Although the Indian Ocean tendency has been downward, it is the most variable of all the oceans and tends to reflect the variability of the equatorial time series. Despite this variability, both Indian Ocean in situ and satellite SST agree remarkably well. Annual trends at all locations show no statistical difference between in situ and satellite data sets.

NOAA's Northeast Fisheries Science Center has taken SST observations using a bucket thermometer in conjunction with its annual bottom-trawl surveys. These SST observations have been conducted each spring since 1968 and each fall since 1963 (Figure II-3). The trawls have been made at approximately 300 stations from Cape Hatteras to the Gulf of Maine, including the Middle Atlantic Bight, and from the coast to the edge of the continental shelf.

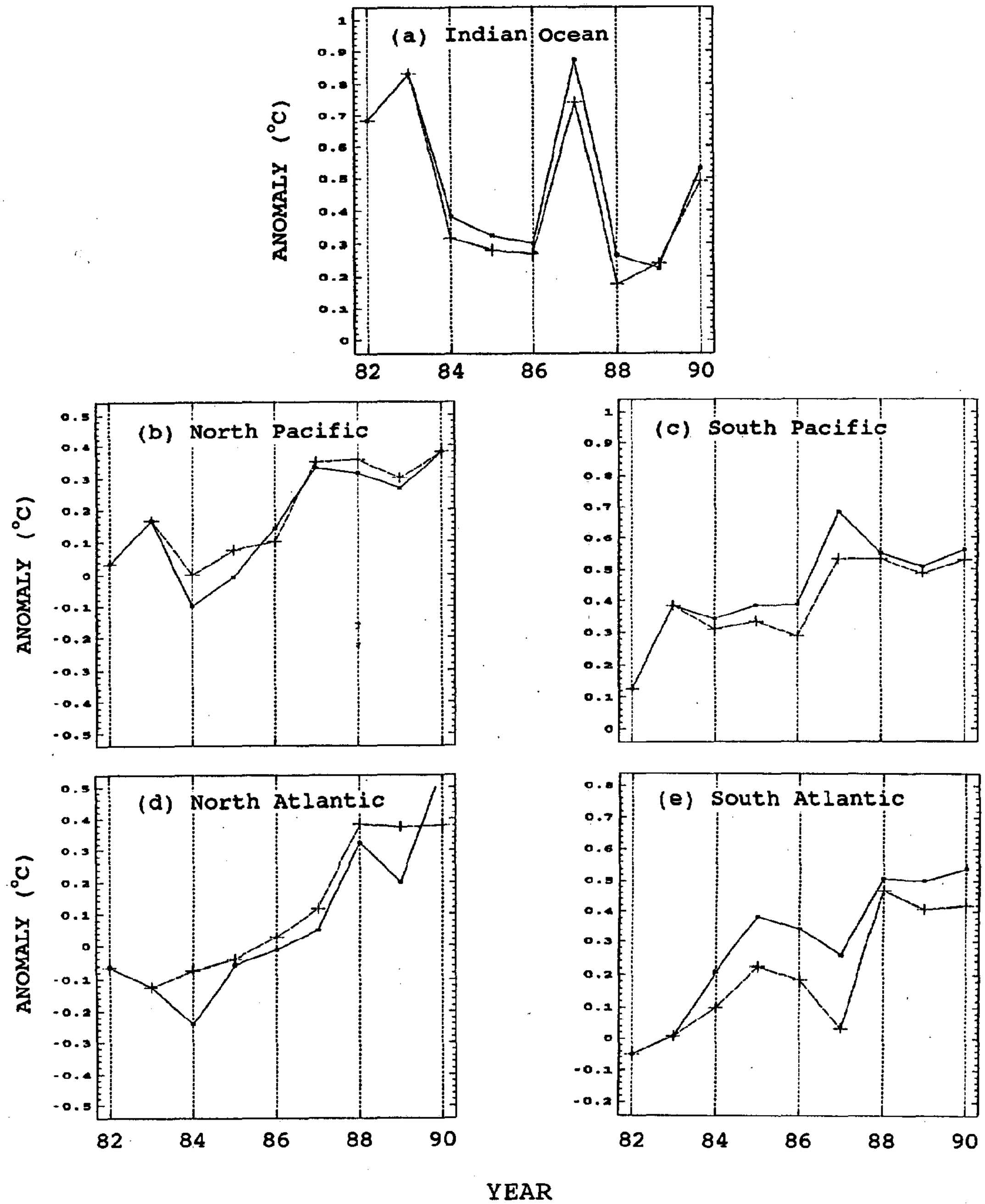


Figure II-2 (a)-(e). Annual mean SST anomalies from satellite multi-channel sea surface temperature (MCSST) (solid line) and <u>in situ</u> buoys and ships (dashed line) for the 5 major ocean basins: (a) Indian Ocean; (b) North Pacific; (c) South Pacific; (d) North Atlantic; (e) South Atlantic. MCSST data for 1982-1983 have not been corrected for aerosol effects from El Chichon volcano and are temporally replaced with <u>in situ</u> SST data. (Courtesy Alan E. Strong, Satellite Applications Laboratory, NOAA National Environmental Satellite, Data, and Information Service)

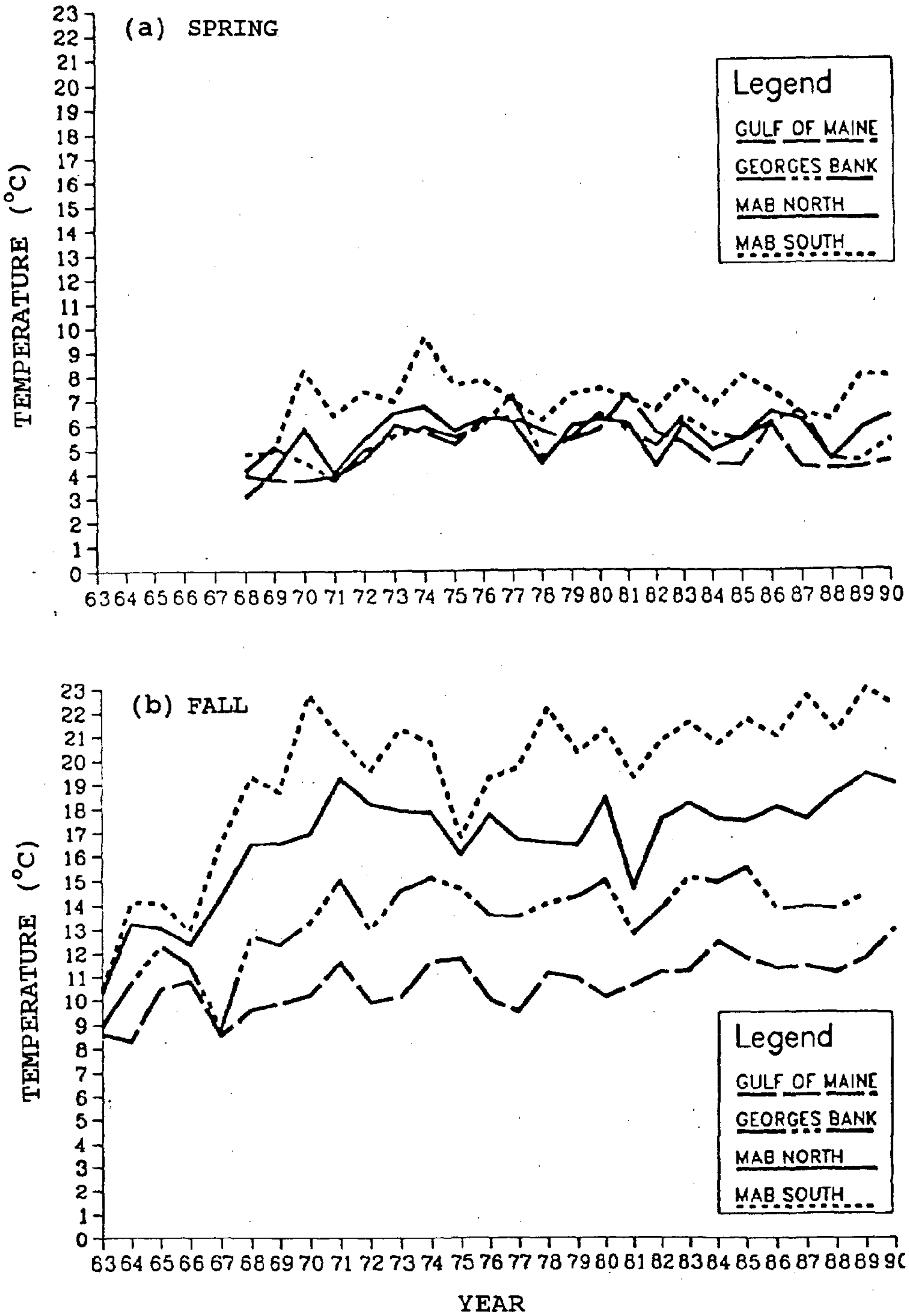


Figure II-3 (a)-(b). Average sea surface temperature for (a) spring and (b) fall in the Gulf of Maine, Georges Bank, northern Middle Atlantic Bight (MAB North), and southern Middle Atlantic Bight (MAB South). (Courtesy Tamara J. Holzwarth-Davis and David G. Mountain, Northeast Fisheries Science Center, NOAA National Marine Fisheries Service)

To examine the hypothesis that major variation in shelf-water temperatures are coherent over large areas, the historical record of SST for the continental shelf from Chesapeake Bay to southern Labrador was divided into 19 areas, each consisting of 1 degree quadrangles contiguous with each other. All real-time ship SST data for the period from March 1971 to December 1983 were used in the analysis. Data for the 10-year base period (March 1971-December 1980) were used to establish the average monthly temperatures and their standard deviations. Figure II-4 shows the anomalies tend to be coherent over large space scales and often for several months at a time. In 1971 for example, temperatures in a large area from southern Labrador to the northeastern Scotian Shelf were higher than normal (by about one standard deviation) during late spring and early summer. Temperatures were near-normal during most of 1972 and 1973, but, the entire region from Hamilton Bank to the Gulf of Maine had below-normal temperatures in late spring and early summer of 1974, with July temperatures being nearly three degrees below normal from northern Nova Scotia to northern Newfoundland (areas 11-16). Evidence of large-scale events, with a time scale of several years and with opposite phase to the north and south of the Gulf of Maine-Georges Bank region (areas 6-7), is evident in the temperature anomaly pattern for 1981 through 1983.

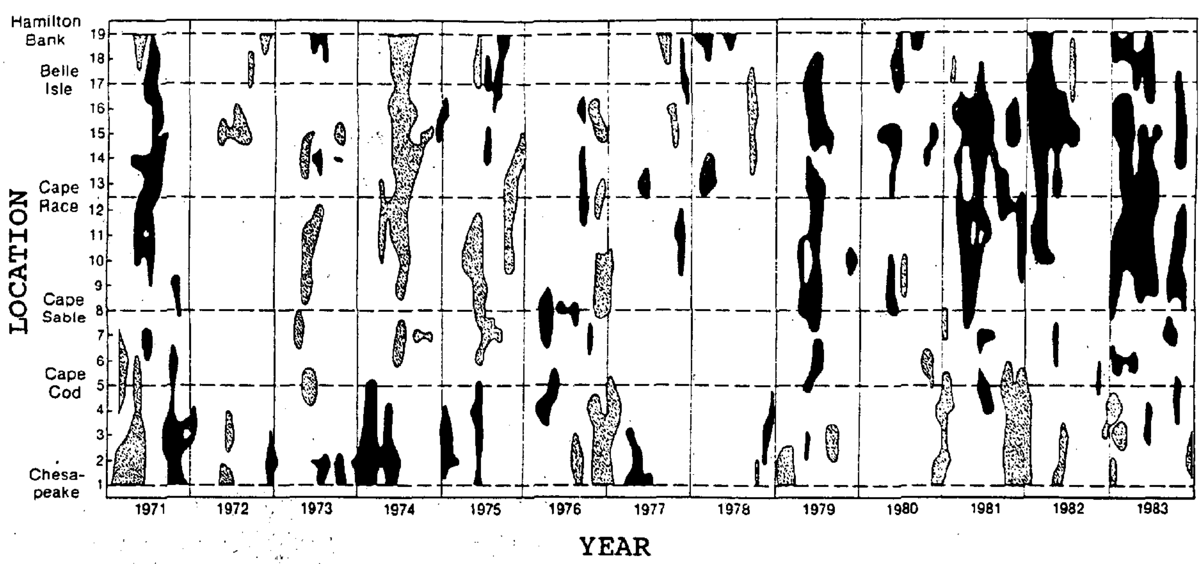


Figure II-4. Contoured plot of monthly SST anomalies (relative to 1971-80 base period) for 1971-83 for the northwest Atlantic (Chesapeake Bay to southern Labrador). Only anomalies greater than 1°C (solid) and less than -1°C (mottled) which extended through at least two neighboring areas for at least two consecutive months are contoured. (Courtesy Douglas R. McLain, Center for Ocean Analysis and Prediction, NOAA National Ocean Service)

b. Subsurface

The temporal variability of the thermal structure of the deep north Atlantic Ocean has been described using the oceanographic station data files from NOAA's National Oceanographic Data Center. The oceanographic files contain data from about 500,000 hydrographic stations. Average values of temperature at standard depths from 0 to 5500 meters (m) for two 5-year periods (1955-59 and 1970-74) were analyzed and the differences in thermal structure between the two 5-year periods were calculated (i.e., the 1970-74 analyses minus the 1955-59 analyses).

Figure II-5 shows the resulting temperature difference fields along 24.5°N for the two 5-year periods. Throughout most of the north Atlantic basin at the 500 m to 2000 m depth range a warming of at least 0.05°C was observed. A maximum difference exceeding 0.5°C occurred at about 800 m depth at 52°W. Cooling is observed in the upper 500 m of water column in the two portions of the basin. One is a small region centered on 30°W and a second is a larger region centered around 60°W. Cooling of less than 0.05°C occurred along the ocean bottom.

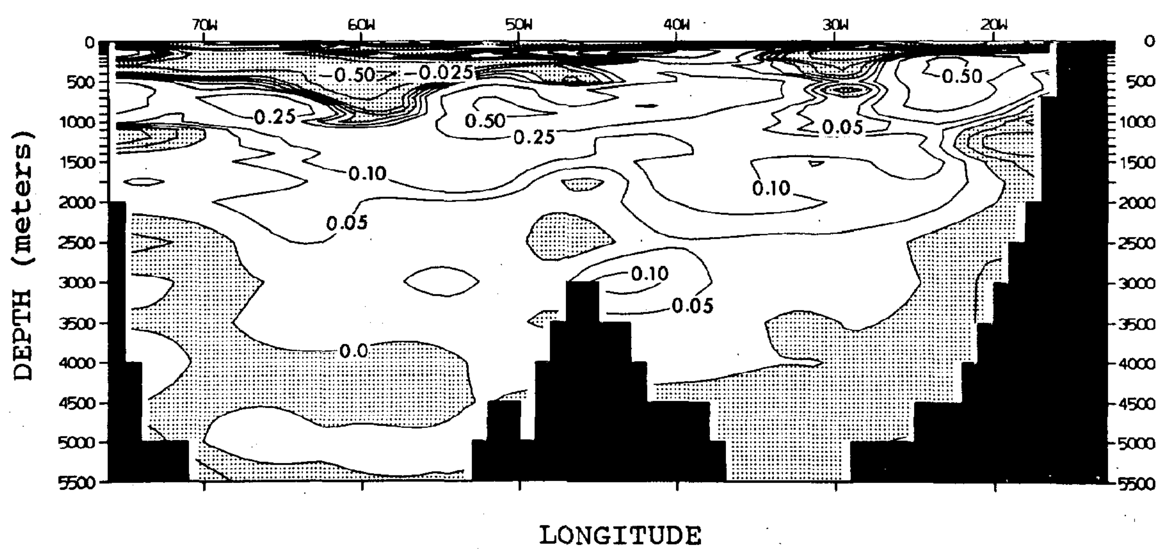


Figure II-5. Temperature difference (°C) as a function of depth along 24.5°N for 1970-74 minus 1955-59. Dot shading indicates negative values. (Courtesy Sydney Levitus, National Oceanographic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

Further comparisons can be made by inspecting the temperature difference fields along 36.5°N. Figure II-6 shows the difference field for this latitude between the two 5-year periods. The major feature here is the cooling in the surface layers and warming at intermediate depths.

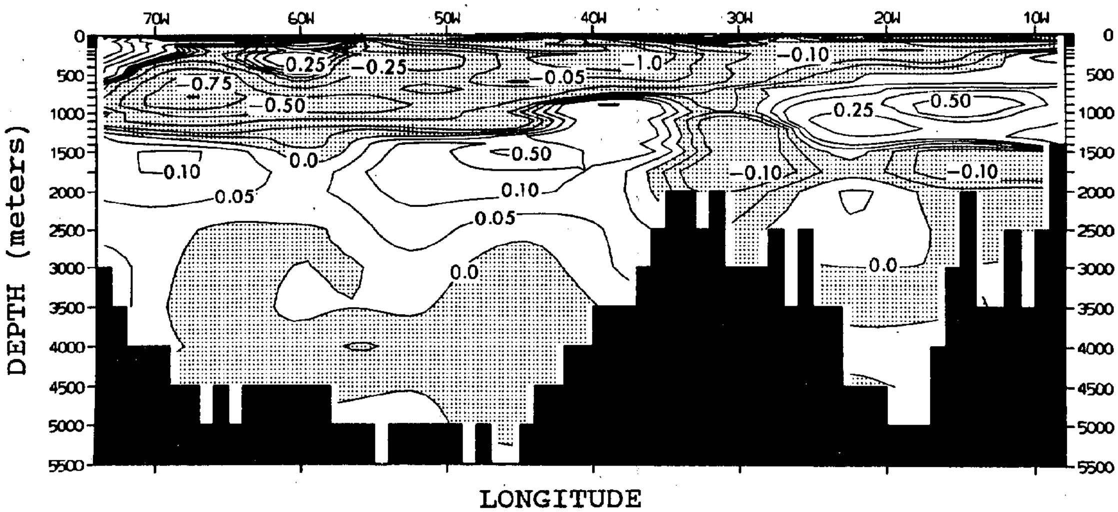


Figure II-6. Temperature difference (°C) as a function of depth along 36.5°N for 1970-74 minus 1955-59. Dot shading indicates negative values. (Courtesy Sydney Levitus, National Oceanographic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

Figure II-7 shows differences in temperature between the two 5-year periods at 1750 m depth. Results of this analysis and others indicate that the thermal structure of the deep north Atlantic Ocean has, in fact, changed on decadal time scales, notably in the 1950s through the 1970s. The temperature-difference field indicates that most of the north Atlantic warmed at this depth on the order of 0.05°-0.25°C.

In addition to hydrographic casts, subsurface ocean temperature data can be collected with a bathythermograph, a device for obtaining a record of temperature against depth from a ship underway. From the early 1940s through the early 1970s, subsurface temperature profiles were collected from ships using mechanical bathytheromographs (MBT). In using recent years, temperature versus depth profiles have been made using expendable bathythermograph probes (XBT). The NOAA Northeast Fisheries Science Center has collected bottom temperature measurements using MBT and XBT probes in conjunction with the Center's biannual trawl surveys. The time series plots of the average bottom temperature data are shown in Figure II-8. In the spring, the bottom temperatures in the different regions are all approximately equal, although the southern Middle Atlantic Bight temperatures are about 1°C warmer than those in the other regions. In the fall, the bottom

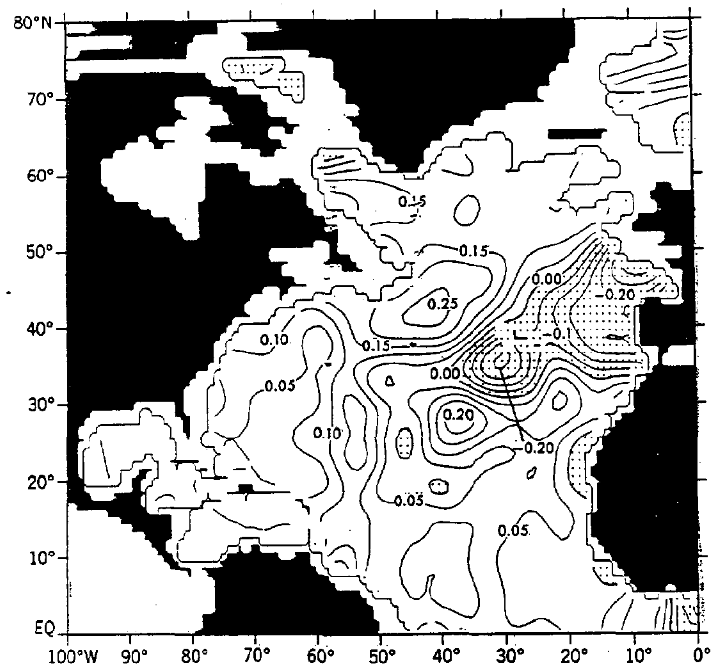


Figure II-7. Temperature difference (°C) at 1750 m depth for 1970-74 minus 1955-59. Dot shading indicates negative values. (Courtesy Sydney Levitus, National Oceanographic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

temperatures in the Gulf of Maine are a few degrees colder than the other areas, which exhibit approximately similar temperatures. The colder bottom temperatures in the Gulf of Maine are due in large part to the Gulf being considerably deeper than the other three regions and seasonal surface warming does not penetrate to the bottom.

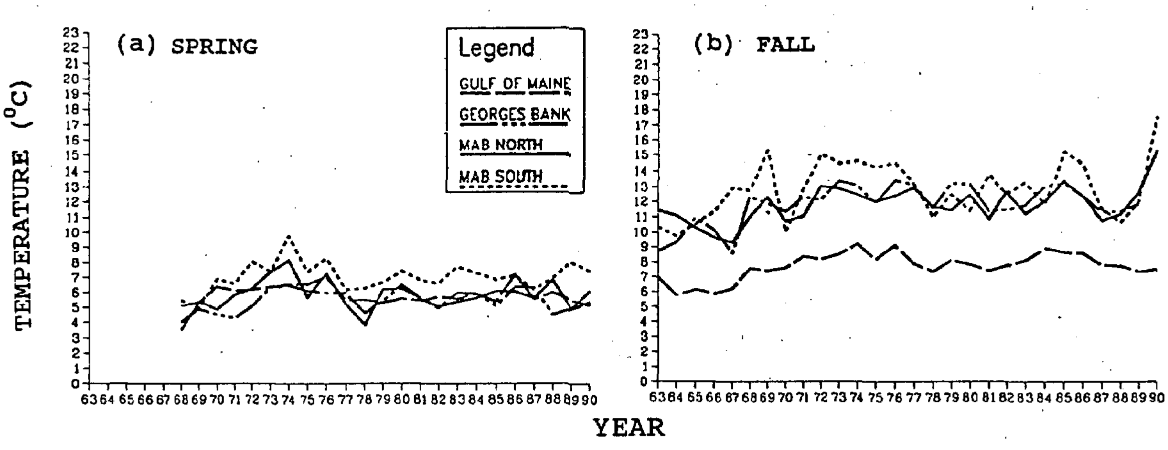


Figure II-8 (a)-(b). Average bottom temperature (°C) in (a) spring and (b) fall for Gulf of Maine, Georges Bank, northern Middle Atlantic Bight (MAB North), and southern Middle Atlantic Bight (MAB South). (Courtesy Tamara J. Holzwarth-Davis and David G. Mountain, Northeast Fisheries Science Center, NOAA National Marine Fisheries Service)

SALINITY

Salinity is the measure of the dissolved salts in seawater. Evaporation, precipitation, and ice formation and melting are processes that influence salinity. The normal range of salinities in the open ocean is small, usually from about 33 parts per thousand (ppt) to 37 ppt, with the average ocean salinity being about 35 ppt. Surface salinity values are lower at higher latitudes and near the equator where precipitation exceeds evaporation. Salinity is highest in the middle latitude subtropical gyres where evaporation exceeds precipitation. Subsurface ocean waters exhibit relatively small changes in salinity compared to surface waters. These small changes in salinity are important in identifying deepwater masses.

a. North Atlantic Ocean

The temporal variability of salinity in the north Atlantic Ocean has been described using the oceanographic station data files of NOAA's National Oceanographic Data Center. Average values of salinity based on 1° squares were analyzed at standard depths from 0 to 5500 m for the 5-year periods 1955-59 and 1970-74 and differences between the periods were calculated (i.e., 1970-74 analyses minus the 1955-59 analyses). Upper ocean (0-150 m) and deep ocean (to 5500 m) salinity differences between the two 5-year periods exhibit statistically significant changes. Figure II-9 shows the salinity difference field for the sea surface and 150 m depth. At the surface, one major feature is the negative anomaly north of 42°N indicating that the subarctic gyre was fresher during 1970-74 compared to 1955-59. Maximum freshening occurred east of Newfoundland where a value of -0.5 ppt exists. A positive salinity anomaly occurs along 39°N that extends southward along the east coast of the United States as well as in the 25°-45°N longitude belt. A negative anomaly occurs in the tropics with the largest midocean change being on the order of -0.05 ppt. The major features for the 150 m depth are similar to those at the sea surface. The salinity maximum increase centered along 39°N at the sea surface now extends further northward across the subtropical gyre. The large changes off the coasts of South America and Africa are considerably reduced. The subarctic gyre just east of Newfoundland shows the greatest decrease (to -0.15 ppt at 150 m). This is 0.35 ppt smaller difference than the surface counterpart for this feature. For the 150 m depth, a major difference occurs in the eastern half of the gyre as opposed to the western half for levels higher in the water column.

Evidence of the temporal variability in the salinity structure of the deep north Atlantic Ocean is presented in Figure II-10. The figure shows the difference fields of salinity for the two 5-year periods along 24.5°N and 36.5°N latitudes. Clear basinwide changes have occurred between year groups at both latitudes. At 24.5°N,

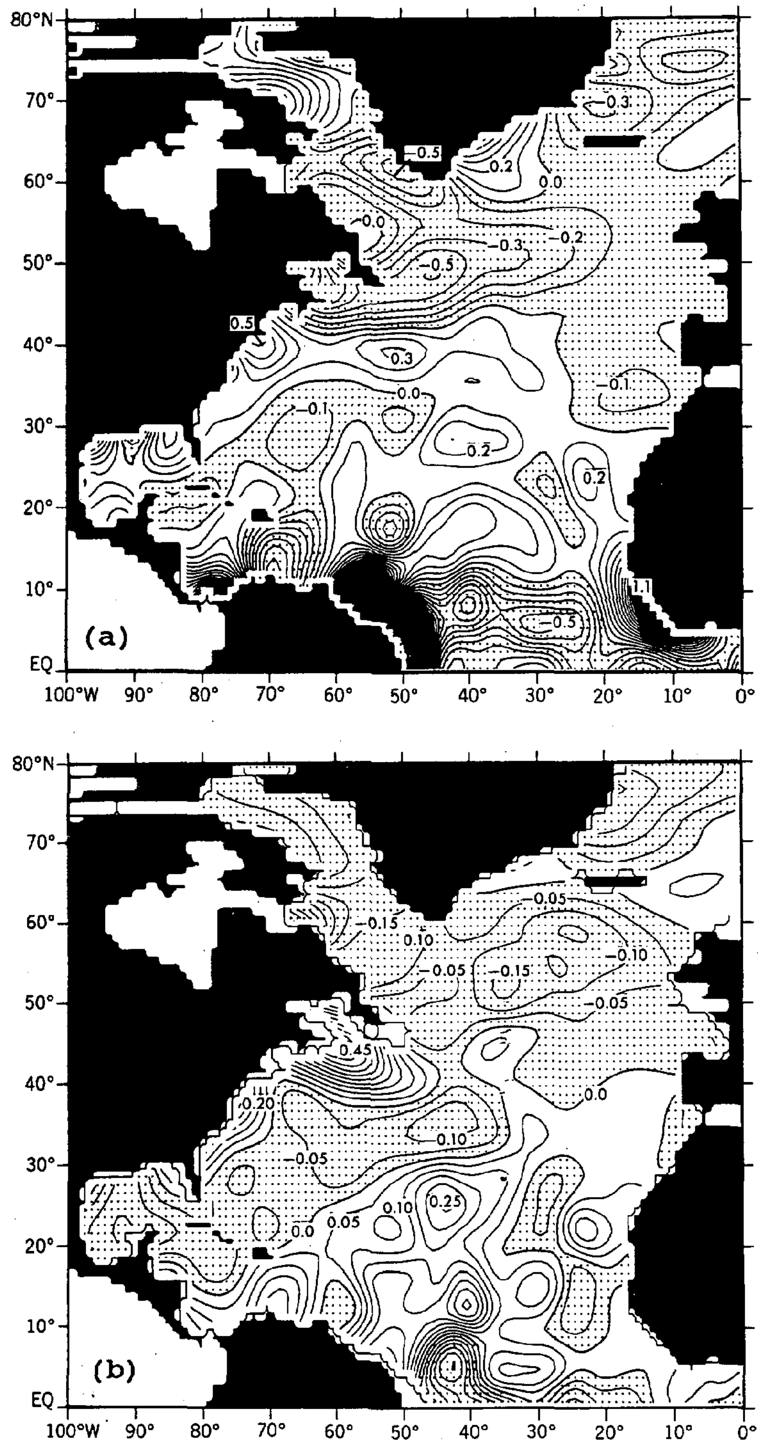


Figure II-9 (a)-(b). Salinity difference in parts per thousand (ppt) for 1970-74 minus 1955-59 at the (a) surface and (b) 150 m depth. Dot shading indicates negative values. (Courtesy Sydney Levitus, National Oceanographic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

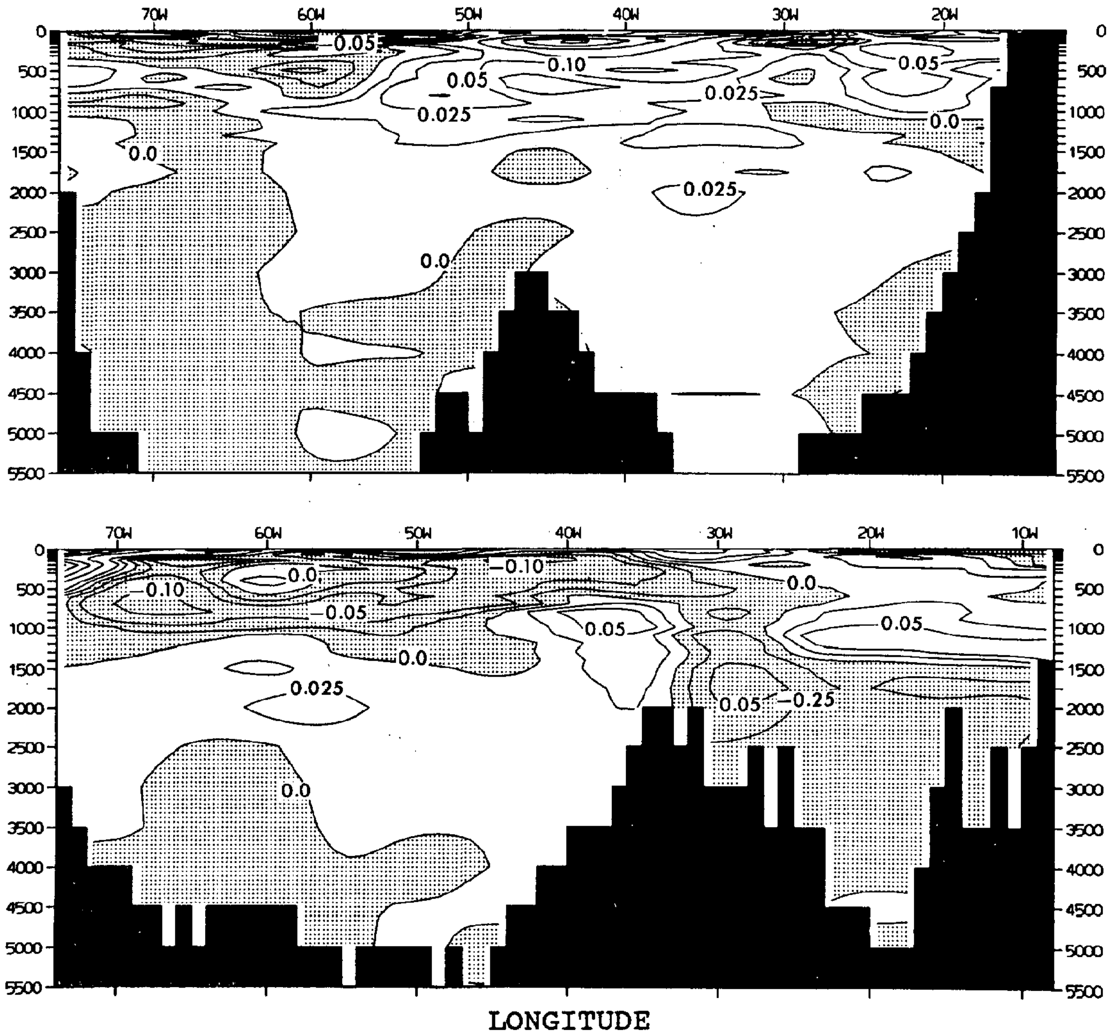


Figure II-10. Salinity difference in parts per thousand (ppt) as a function of depth along (top) 24.5°N and (bottom) 36.5°N for 1970-74 minus 1955-59. Dot shading indicates negative values. (Courtesy Sydney Levitus, National Oceanographic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

freshening is seen at intermediate depths in the western part of the Atlantic. A slight freshening is seen at deeper levels in the Atlantic west of the mid-Atlantic ridge. The eastern Atlantic exhibits a slight increase in salinity at deeper levels. At 36.5°N freshening is observed west of 30°W at depths exceeding 3000 m. West of the mid-Atlantic ridge a slight increase in salinity is observed in the 1500 to 2500 m layer. A region of freshening is observed in deeper layers. East of the mid-Atlantic ridge salinity has freshened at nearly all depths beneath the 1500 m level.

Figure II-11 shows interyear differences of salinity at 1750 m depth. Relatively large differences have occurred over most of the

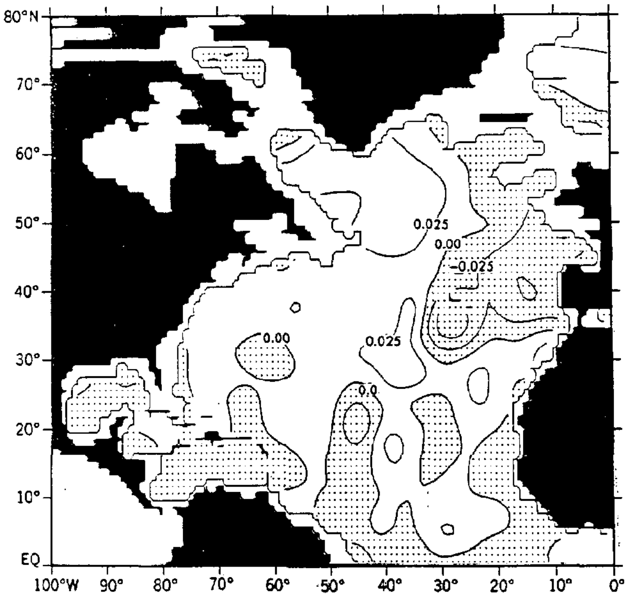


Figure II-11. Salinity difference in parts per thousand (ppt) at 1750 m depth for 1970-74 minus 1955-59. Dot shading indicates negative values. (Courtesy Sydney Levitus, National Oceanographic Data Center, NOAA National Environmental Satellite, Data, and Information Service)

the north Atlantic Ocean. The difference fields show that a salinity increase occurred throughout most of the area. The exception is at mid-latitudes in the eastern Atlantic where a freshening of the order of 0.025 ppt was observed. This analysis indicates that the salinity structure of the deep north Atlantic Ocean changes on decadal time scales.

b. Northeastern Continental Shelf

Surface salinities are monitored across the northeastern United States continental shelf in conjunction with the NOAA National Marine Fisheries Service's Ships of Opportunity Program. Surface salinity measurements have been collected monthly from ship transits across the Gulf of Maine since 1977 and the Middle Atlantic Bight since 1976. Surface salinity for the Gulf of Maine and Middle Atlantic Bight transects are presented as contoured time-space plots (Figures II-12 and II-13). Portrayed are the salinities during 1990 and the departure of these salinities from the 1978 through 1987 average values.

Observed salinities in the Middle Atlantic Bight ranged from a low of 25.4 ppt nearshore in early February to a high of 36.4 ppt in water at the offshore end of the transect in late February (Figure II-12). Below average salinities were observed in April to July beyond the shelf break when fresher shelf water moved well offshore from normal. Over most of the transect, for the remainder of the year salinities were generally near average. In the Gulf of Maine, time-space distribution of surface salinity in 1990 (Figure II-13) generally exhibits a pattern of positive anomalies to an extent not seen during the term of record.

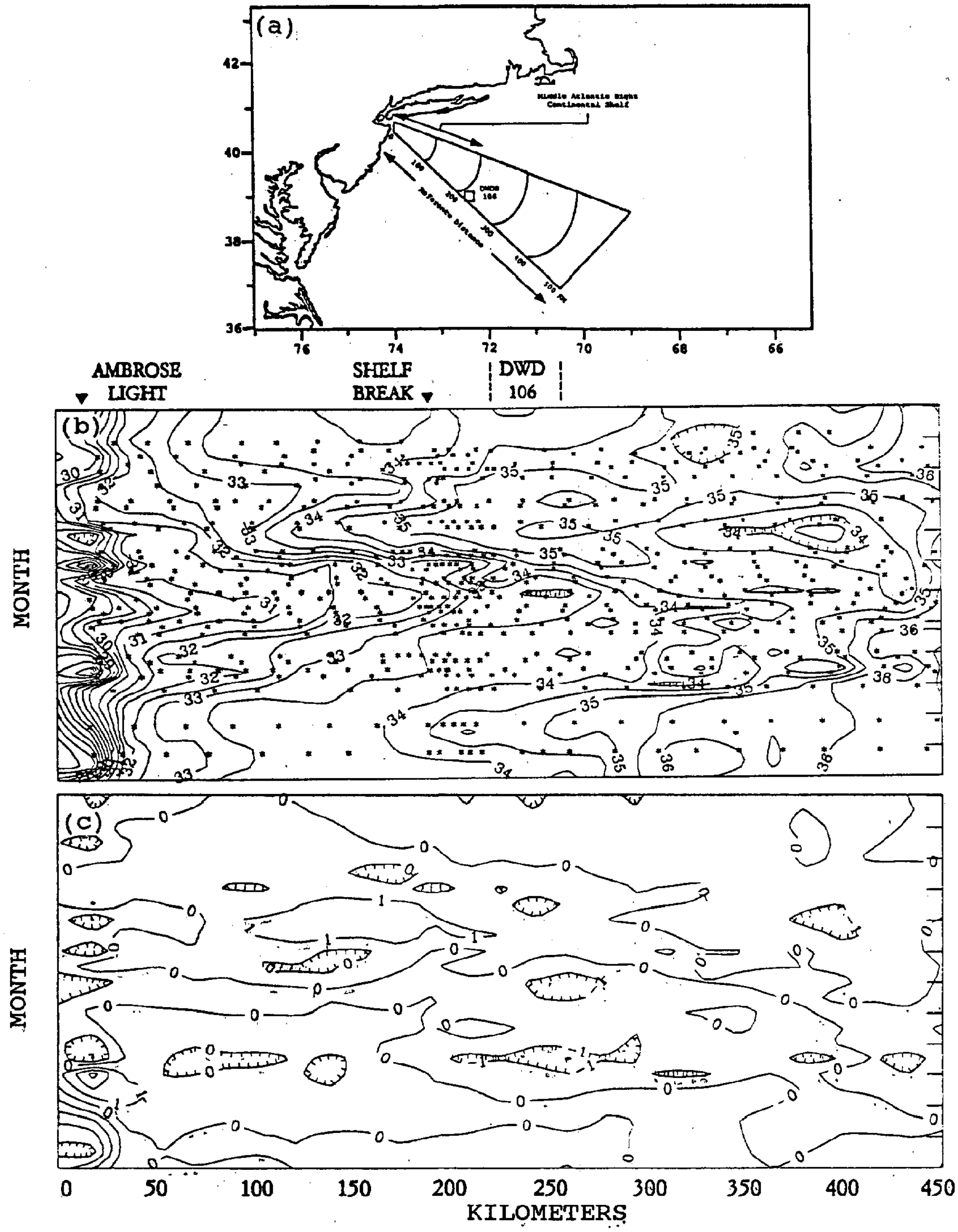


Figure II-12 (a)-(c). Surface salinity for the Middle Atlantic Bight transect during 1990: (a) Middle Atlantic Bight monitoring transects, 1976-1990; (b) measured values (ppt) in time and space (dots indicate sampling locations); (c) anomalies in time and space based on 1978 through 1990 means. (Courtesy Jack W. Jossi and Robert L. Benway, Northeast Fisheries Science Center, NOAA National Marine Fisheries Service)

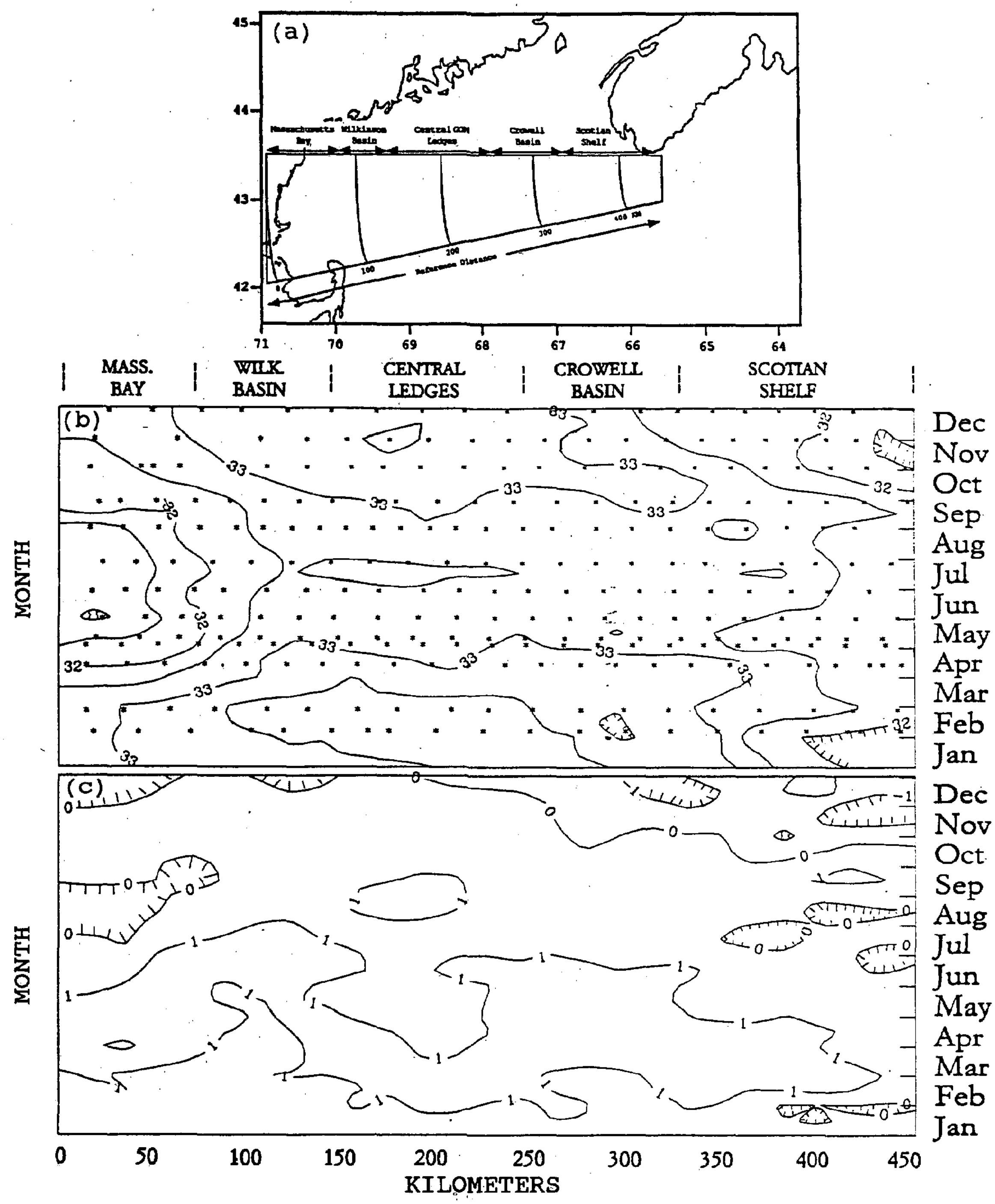


Figure II-13 (a)-(c). Surface salinity for the Gulf of Maine transect during 1990: (a) Gulf of Maine monitoring transects, 1977-1990; (b) measured values (ppt) in time and space (dots indicate sampling locations); (c) anomalies in time and space based on 1978 through 1990 means. (Courtesy Jack W. Jossi and Robert L. Benway, Northeast Fisheries Science Center, NOAA National Marine Fisheries Service)

SEA LEVEL

Changes in sea level have practical as well as scientific interest. Awareness of the importance of monitoring and understanding long-term sea level variations has expanded greatly in recent years because of its relationship to global climate change. Scientists have reached a consensus that if global warming occurs in the coming decades, a change of sea level, with serious consequences for coastal areas of the world, is a real possibility.

Sea level has long been measured by conventional tide gauges at many sites. Globally, the records indicate a rise of about 10 to 30 centimeters over the last century. Exceptional cases where sea level is actually falling occur in areas known to be undergoing isostatic rebound as a result of the global deglaciation. But even after allowing for postglacial rebound and tectonic effects, there is observational evidence for sea level rise. The fundamental observational problem is that sea level is subject to large variations on an interdecadal scale. In addition, the stations with long records are poorly distributed geographically (i.e., aggregated in Europe, Japan, and the U.S. and biased toward the Northern Hemisphere).

Recent technologies are proving important to the significant advance of global sea level monitoring. The Global Positioning System, absolute gravity, and Very Long Baseline Interferometry are being used to measure land movements that corrupt tide gauge records. Satellite altimeters give global coverage of sea level variation and have proven particularly well suited for study of tropical phenomena such as El Nino and transport of western boundary currents. Properly monitoring and interpreting long-term sea level involves a wide range of geophysical and geodetic measurements in an integrated global observation system to understand the reasons for sea level change, make predictions of future behavior, and evaluate economic and social effects.

a. Tide Gauges

Concern over the consequences of global warming has led to increased interest in determinations of the rate of sea level rise from historical tide gauge records. Published values for global sea level rise for the last 50-100 years vary from about 1 to 3 millimeters per year (mm/yr), with uncertainties ranging from 0.015 to 0.90 mm/yr. While there is not much doubt that global sea level is rising, the scatter of results makes impossible a meaningful interpretation of data from specific locations.

The disparity of sea level values is not attributable to instrument error; long-term trends computed at adjacent sites often agree to within a few tenths of a millimeter per year. Instead, the differing estimates of global sea level rise appear to be in large part due to using data from gauges located at tectonic plate boundaries, where changes of land elevation give fictitious sea level trends. Also, virtually all gauges undergo subsidence or uplift due to postglacial rebound (PGR) from the last deglaciation at a rate comparable to or greater than the secular rise in sea level. In addition, short (decades) tide gauge records are of little use for determining the global trend in sea level because seasonal and annual signals are so large and variable that the smaller, longer-period signals are obscured.

The value for mean sea level rise obtained from a global set of 21 stations in 9 oceanic regions avoiding these biases and with an average record length of 76 years during the period 1880-1980 is 1.8 mm/yr + or - 0.1 mm/yr. Figure II-14 gives plots of the filtered data for one station in each oceanic region for 1880-1980 with (heavy dots) and without correction for PGR.

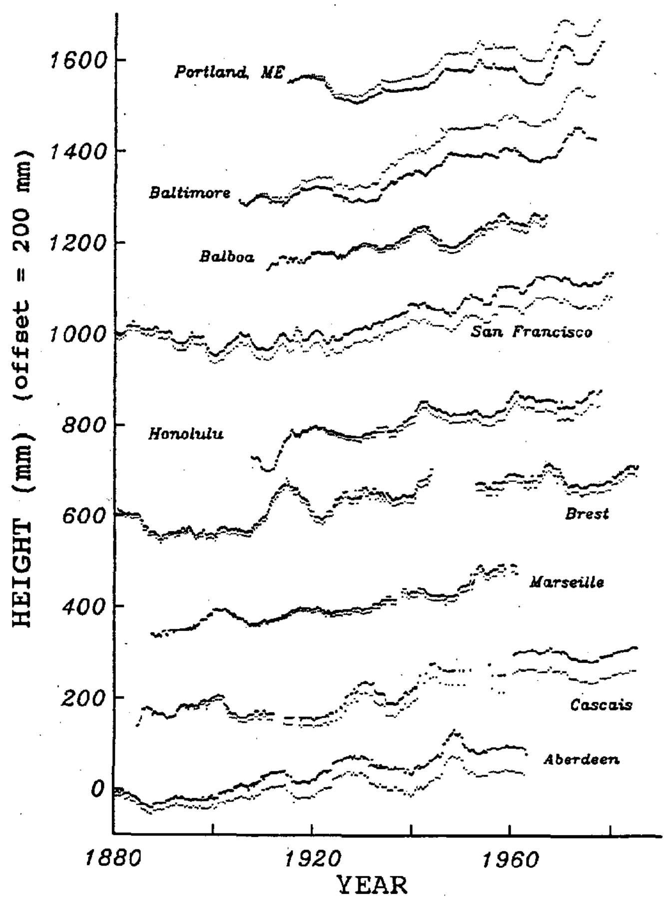


Figure II-14. Median filtered sea level records with (dark) and without (light) postglacial rebound (PGR) correction for one member of each sea level region. (Courtesy Bruce C. Douglas, Chief, Geosciences Laboratory, NOAA National Ocean Service)

b. Satellite Altimetry

Since the beginning of the U.S. Navy Geosat altimeter mission in 1985 NOAA/National Ocean Service has prepared altimeter data sets for distribution to the international scientific community and has actively participated in oceanographic research based on these data. Although the satellite failed in late 1989, this 4.5-year satellite mission was the most successful of its kind. About 500,000 observations of sea level, wind speed, and wave height were collected daily over the global oceans, resulting in an order of magnitude more altimeter data than had been obtained during all previous missions. These data have been used by NOAA to study and monitor sea level variations in the tropical oceans as they relate to global weather and climate (Figure II-15). During the past year a number of new Geosat data sets have been prepared by NOAA for distribution to the oceanographic community:

1. <u>GDRs</u>. The NOAA Geosat geophysical data records (GDRs) have recently been upgraded by incorporating a significantly more accurate satellite orbit, corrections for water vapor, tides, dry troposphere, and geoid. These new GDRs, which are being distributed on 7 CD-ROMs, have enabled sea level to be determined with far greater accuracy than before. Comparison with island tide gauge data in the tropical Pacific indicates accuracies of about 3 cm root mean squares for monthly mean sea level.

2. <u>XDRs</u>. The first 18 months of the Geosat altimeter sea level data (April 1985 to September 1986) are secret, but permission was given to NOAA by the U.S. Navy to generate an unclassified version of the data that can be used for sea level variability studies. These unclassified data are expressed in a form known as crossover differences (XDRs). A global set of approximately 44 million XDRs was computed at the secure facility operated by NOAA at the Johns Hopkins Applied Physics Laboratory, and these are being made available to the research community on a set of 7 CD-ROMs. The XDRs enable computation of continuous sea level time series spanning the period 1985-89 and have provided the first comprehensive description of interannual variations associated with the El Nino event in the Pacific Ocean.

3. <u>Southern Hemisphere GDRs</u>. In 1990 NOAA obtained permission from the Navy to declassify those Geosat geodetic mission GDRs covering the ocean region adjacent to Antarctica (60°S to 72°S). The average cross-track spacing of these data is typically 2 to 3 km at 60°S, providing very high spatial resolution for geophysical studies. These GDRs are contained on two 9-track tapes. NOAA is also actively supporting the newest satellite altimeter, the European Space Agency (ESA) Remote Sensing Satellite (ERS-1), launched in July 1991. NOAA personnel are assisting ESA in areas of calibration and verification and will use the fast delivery altimeter data to perform monthly monitoring of tropical sea level.

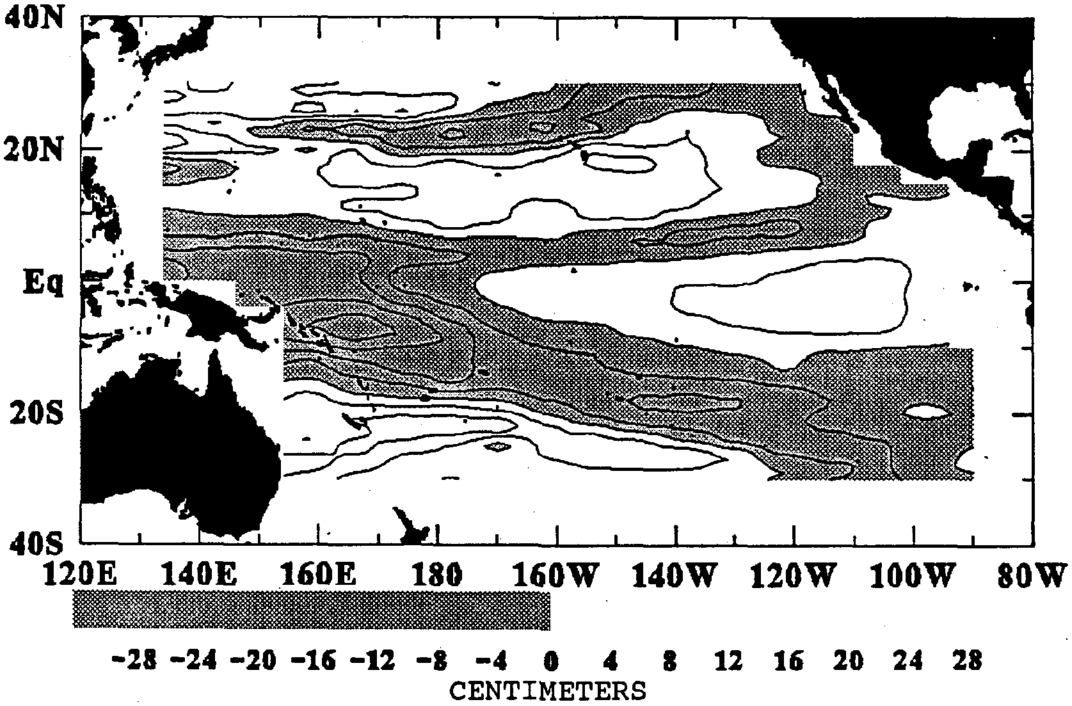


Figure II-15. Sea level anomaly in the tropical Pacific averaged over the 1-year period November 1986-87. Anomalies are relative to the mean over the first year of the Geosat mission, April 1985-86. Contours are at 4 cm intervals, negative shaded. This map depicts the 1986-87 El Nino when water from the western equatorial Pacific was displaced primarily to the east and north. (Courtesy Robert E. Cheney, Chief, Satellite and Ocean Dynamics Branch, Geosciences Laboratory, NOAA National Ocean Service)

OCEAN TRANSPORT

The role of ocean circulation in transporting heat and modifying the effects of global climate change is not well understood. Recent research has identified the Atlantic Ocean latitude band 20°N to 30°N as having the largest poleward heat flux in the North Atlantic basin. Figure II-16 shows the variability within the Florida Current in ocean transport. This monitoring was done using measurements of the cross-stream voltage between Florida and Grand Bahama Island, generated by the flow of the Florida Current through the Earth's magnetic field as measured by a submarine cable along the seafloor. The fluctuations in the 30-day running mean of the transport (Figure II-16, upper curve) show that there are large seasonal changes in transport and that these fluctuations are larger in some years than others. It is not known at this time whether these fluctuations are an indicator of climate variability or long-term change. The yearly mean values (Figure II-16, bottom curve) do not show significant change in the mean transport of 32 Sverdrups.

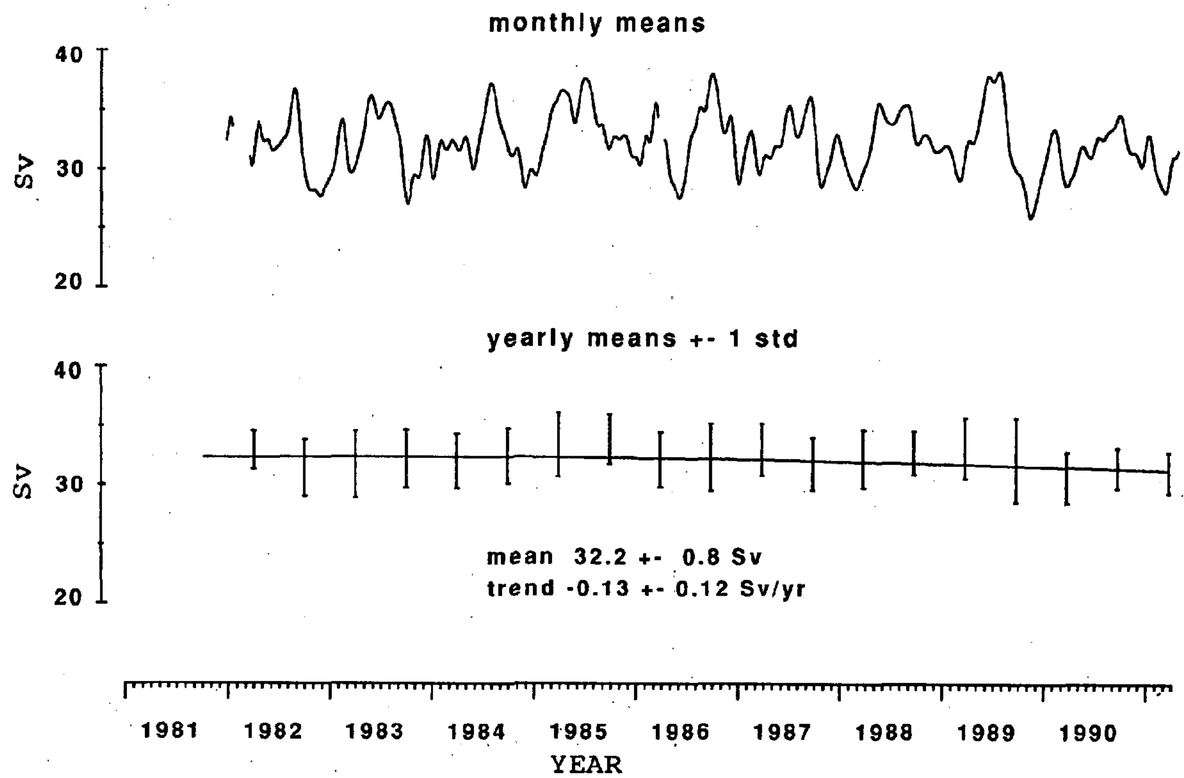


Figure II-16. Monthly mean transport for Florida Straits (27°N) derived from voltage measurements made between Settlement Point, Grand Bahama Island, and near Jupiter Inlet, Florida. Monthly means (top curve) and yearly means (bottom curve) are given. Sv=Sverdrups ($10^6 m^3/sec$). (Courtesy Jimmy C. Larsen, Pacific Marine Environmental Laboratory, NOAA Office of Oceanic and Atmospheric Research)

COASTAL UPWELLING

Upwelling regions are among the most biologically productive areas of the ocean. The most important upwelling areas are in the eastern boundary currents off California, Peru, northwest Africa and southwest Africa. Not only are upwelling regions of high economic importance (yielding up to 50 percent of the world's fish catches), but they strongly influence adjacent coastland weather and climate. Increasing alongshore wind stress, which drives coastal upwelling, has been linked to long-term climate variation and change. Changes in the rate of coastal upwelling have been used as an indicator of climate variability. Direct observations of upwelling are not available. However, a coastal upwelling index, based on an estimate of the alongshore wind stress (the driving mechanism for upwelling), has been used to calculate variations of upwelling intensity along the west coast of the U.S. (Figure II-17).

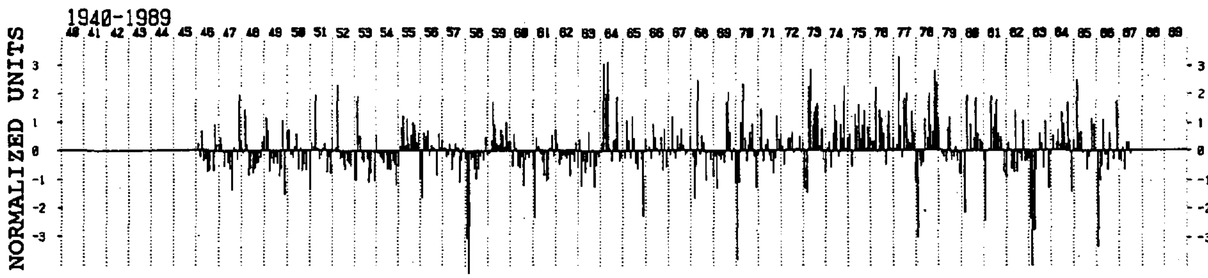


Figure II-17. Bakun Coastal Upwelling Index. Offshore Ekman Transport at 39°N, 125°W. (Courtesy Andrew Bakun, Chief, Pacific Fisheries Environmental Group, NOAA National Marine Fisheries Service)

The first edition of the NOAA ENVIRONMENTAL DIGEST described a process by which global warming could result in the amplification of heating during summer intensifing the thermal low-pressure cell over the coastal landmass in upwelling regions. The increased onshore-offshore pressure gradient induces strengthened alongshore wind. Evidence was presented of substantial multi-decadal increases in alongshore wind stress off California, Peru, Morocco, and the Iberian Peninsula. Further evidence of increasing alongshore wind stress is presented for the northwest coast of Africa in Figure II-18. Additional evidence for this hypothesis is found in the trends in atmospheric pressure in the northwest Africa interior. The thermal low in the interior of northwest Africa appears to have been intensifying in an especially dramatic manner. This is being done in phase with the strongly increasing wind trends along the west African coast. Meteorological data in the African interior is rather sparse and this might be suspected as being involved in the trend. However, actual measured barometric pressure from a group of stations in north Africa (Tombouctou, Mopti, & Bamako) appear in each case to independently substantiate the trend.

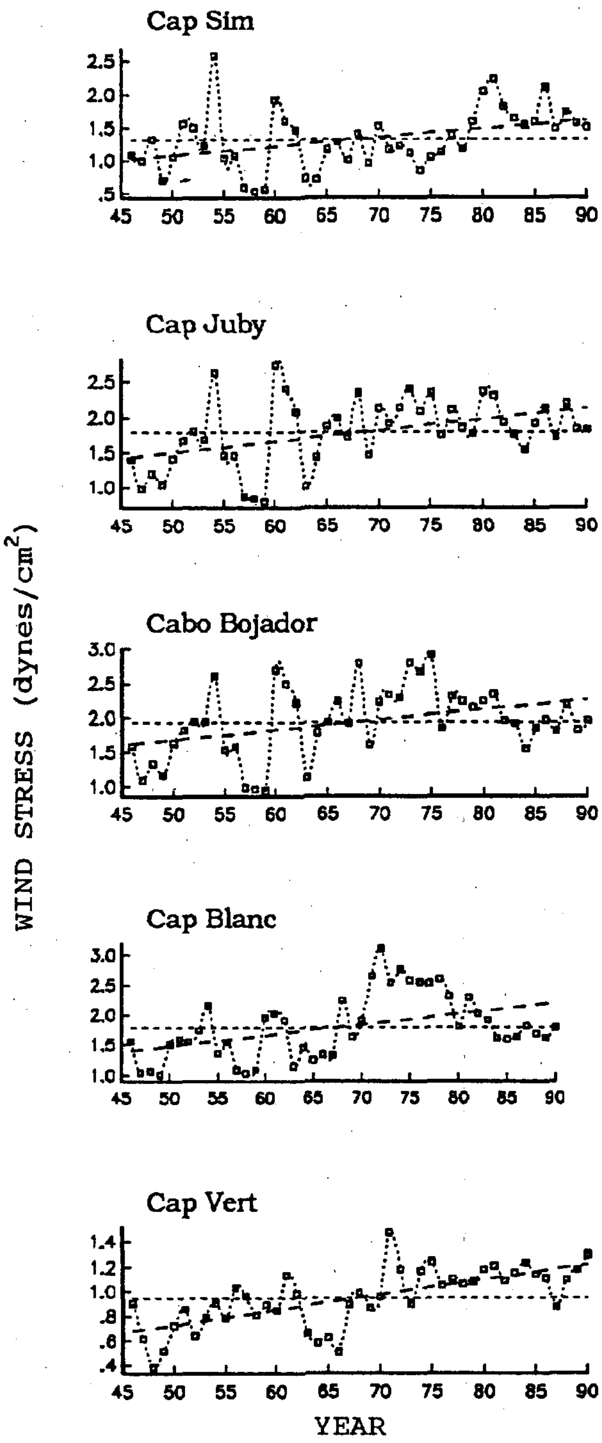


Figure II-18. Monthly estimates of alongshore wind stress (dynes/cm²) off northwest Africa. Linear trend fitted by least squares method (long dashes). (Courtesy Andrew Bakun, chief, Pacific Fisheries Environmental Group, NOAA National Marine Fisheries Service)

LONG WAVES

Global scale ocean dynamics are dominated by the rotation of the Earth. The Coriolis force has an important influence on long waves, fronts, and eddies on many spatial and temporal scales. A special class of motions occur in the vicinity of the equator where the Coriolis force approaches zero.

Equatorial long waves are westward propagating, low frequency, long period, with large north-south scales. Long waves have been seen as 1000 kilometer cusped perturbations in the sea surface temperature front that develops along the equator in the Atlantic Ocean during summer and fall. Such perturbations have been noted in satellite photographs.

The perturbations move westward at speeds varying from 20 to 50 cm/second. The position of these perturbations affect biological productivity, weather, and cross-equatorial heat transport. The movement of long wave crests has been tracked in SST from satellite measurements since 1984. Wave activity reached a minimum in the El Nino year 1987. Waves have been particularly frequent and long-lived in 1989 and 1990 (Figure II-19).

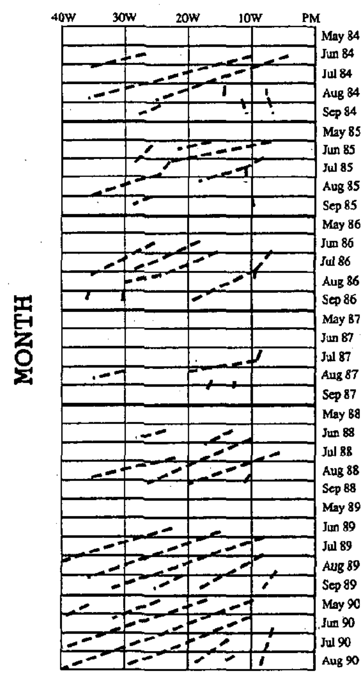


Figure II-19. Positions of long wave crests in the equatorial Atlantic Ocean during May-September, 1984-90. Crests propagate westward at an average speed of about 30 cm/sec. (Courtesy LT John M. Steger, Satellite Applications Laboratory, NOAA National Environmental Satellite, Data, and Information Service)

COASTAL GEODESY/HYDROGRAPHY

Geodesy is the science of measuring the shape of the Earth's surface. The Coast and Geodetic Survey (C&GS) has the capability to accurately determine land subsidence and shoreline movement from its historic data base. Accurate shoreline maps have been produced since the early 1830s. The maps cover the nation's shoreline which has been remapped on an average interval of 30 years. In addition to shoreline maps, the C&GS maintains an archive of aerial film dating from the early 1930s.

Subsidence is the sinking of the ground due to natural or anthropogenic causes. Two areas of the United States, New Orleans-Southern Louisiana and Houston-Galveston, Texas, are experiencing land subsidence due mainly to the withdrawal of groundwater and oil. Detection of this movement has been made possible through the repeated surveying of the National Geodetic Reference System of the C&GS. Releveling efforts over the past 20 years generally show a continuing subsidence of the land areas, although rates of subsidence vary over the entire area.

Between 1963 and 1978, all of the region within 20 miles of Houston had subsided at least 3 decimeters. Figure II-20 shows how Houston's eastern boundary (Pasadena) has subsided since 1976. The dramatic decrease in subsidence east of Houston since 1978 is a result of regulated reductions of water pumping allowed by canal systems providing alternative surface water. No alternative source of water is available for the area west of Houston, which has experienced rapid residential and commercial growth. The regional changes in water levels have a direct relationship to subsidence in the Houston area.

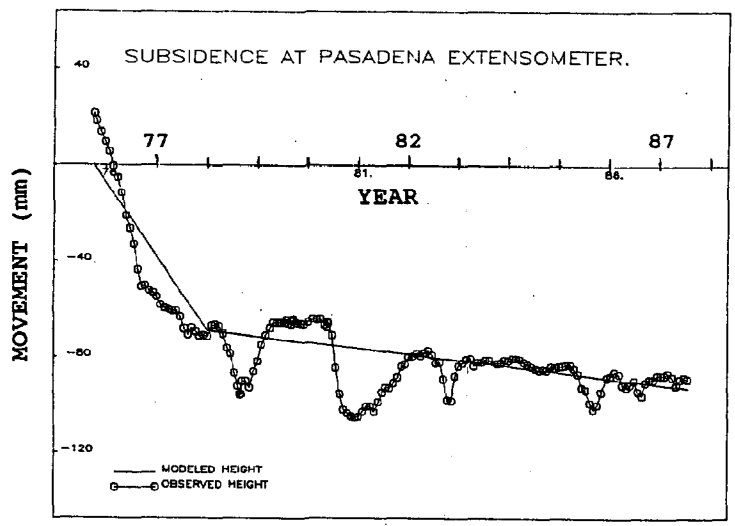


Figure II-20. Subsidence in millimeters (mm) at Pasadena, Texas, 1976-88. (Courtesy R. Sandford Holdahl and David B. Zilkoski. Coast and Geodetic Survey, NOAA National Ocean Service)

Hydrography is the science which deals with the measurement and description of the physical features of bodies of water and their littoral land areas. Special emphasis is usually placed on the elements that affect safe navigation, and the publication of such information for use in navigation. A shoal is an offshore hazard to navigation on which there is a depth of 66 feet (20 m) or less, composed of unconsolidated material. The C&GS monitor areas of shoal development. This information is vital to all mariners for the purposes of safe navigation. C&GS constantly updates its nautical charts with its own hydrographic surveys and input from other government agencies, private industry, and the public.

Fire Island and West Point Shoals, found at the northern end of Cook Inlet, Alaska, are well known dangers to vessels that transit in and out of the Port of Anchorage. For at least fifty years, C&GS surveys have shown that Fire Island Shoal has been steadily moving eastward toward Fire Island encroaching upon the traditional safe navigation route that container ships, oil tankers, and U.S. Navy and Coast Guard vessels have been using since the early 1960s. Fire Island Shoal, as well as others in the vicinity, has been periodically surveyed by the C&GS to determine the precise location, extent, and least depth for the purposes of safe navigation through this portion of Cook Inlet. Hydrographic survey data collected between 1941 and 1987 revealed that Fire Island Shoal has shifted over 1,000 m and has risen from 10 feet (3 m) least depth to 2 feet (0.6 m) above Mean Lower Low Water. West Point Shoal, adjacent to Fire Island Shoal, is relatively new and has been developing since first observed on a 1982 C&GS survey. During a 5-year period the center has shifted 200 m to the west, expanded by approximately 260 m wide and 1,368 m long, and went from a least depth of 9.1 m to 7.6 m (Figure II-21).

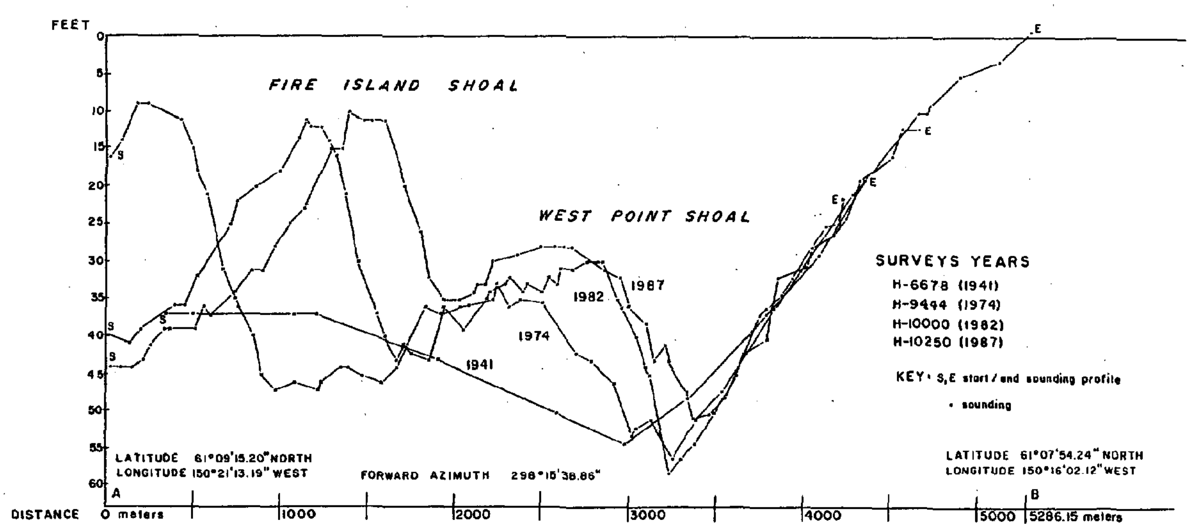


Figure II-21. Sounding profile of Fire Island and West Point Shoals from 1941 to 1987. (Courtesy Dennis J. Hill, Coast and Geodetic Survey, NOAA National Ocean Service)

III. CRYOSPHERE

Sea ice and snow cover are important factors related to the Earth's heat budget and in determining the amount of solar energy reflected back into space (planetary albedo). Latitudinal variations in the Earth's albedo help determine atmospheric circulation and consequently the heat transferred from equator to pole. The processes that accommodate this flux of heat influence both short-term weather and long-term climate. Global scale changes in the volume of ice are an indicator of global temperature change as are the long-term seasonal amounts and extent of snow cover and sea ice.

SEA ICE

Sea ice influences global climate through its effect on planetary albedo. Additionally, it influences energy transfers of heat between the atmosphere and oceans and affects the temperature and salinity structures of the ocean. The melting and freezing that occur at the margins of sea ice produce effects on ocean stability and circulation that promote mixing, upwelling, and nutrient enhancement. These "ice edge effects" act to enhance biological productivity. Measurements of sea ice extent, type, movement, surface temperature, and albedo are important indicators of climate change.

Time series of the monthly areal extent of Arctic sea ice are shown in Figure III-1. The time series shows no clear relationships to the global or Northern Hemisphere surface temperature. For example, the warmest year in the modern record, 1990, was also the year with the minimum in summer Arctic sea ice, but other low Arctic sea ice summers were associated with near zero or slightly negative temperature anomalies.

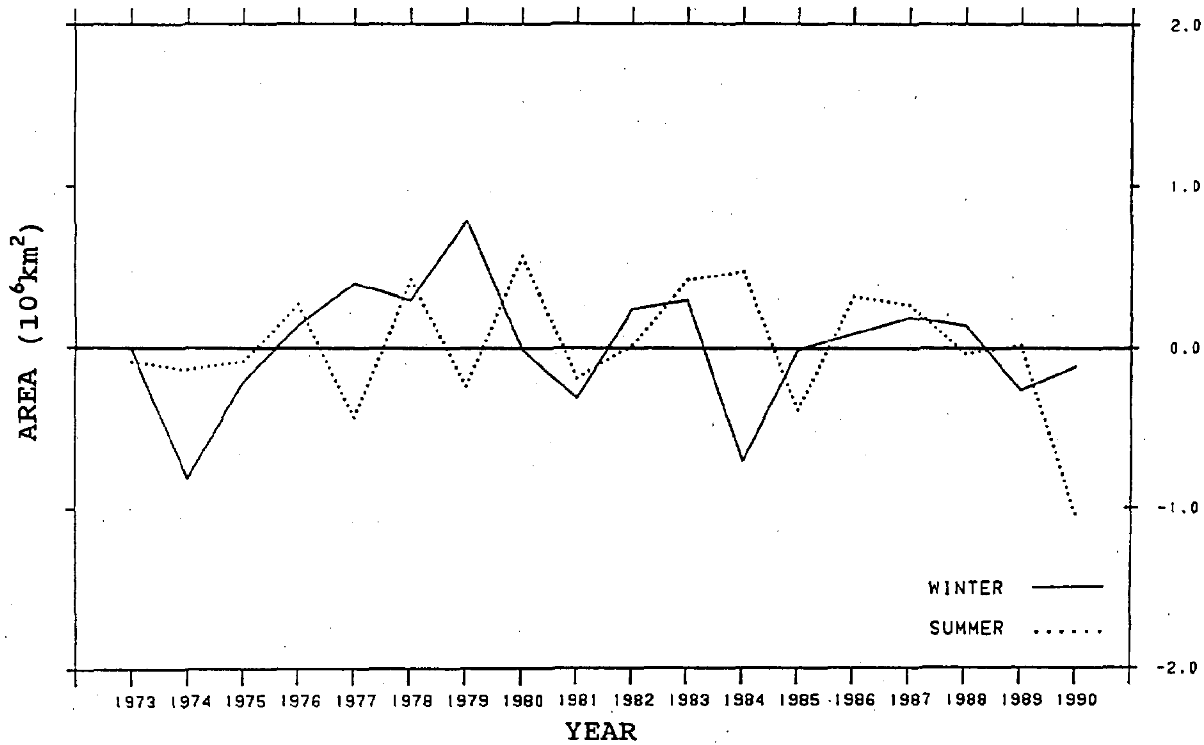


Figure III-1. Time series (1973-90) of the Arctic sea ice anomalies for the northern winter (solid line) which is an average of January and February data and summer (dashed line) which is an average of August and September data. Areas based on satellite remote-sensing data. (Courtesy Climate Analysis Center, NOAA National Weather Service)

The time series of both the Antarctic summer and winter sea ice areas (Figure III-2) show little evidence of long-term trends or relationships to the Southern Hemisphere temperature anomalies. Sea ice anomalies appear to be systematically larger early in the record compared to the recent decade. The larger negative winter anomalies in the late 1970s are associated with the evolution of a persistent polynya, or large ice-free area within the Weddell Sea. Polynyas are thought to be associated with low-frequency fluctuations in the deep-ocean circulation.

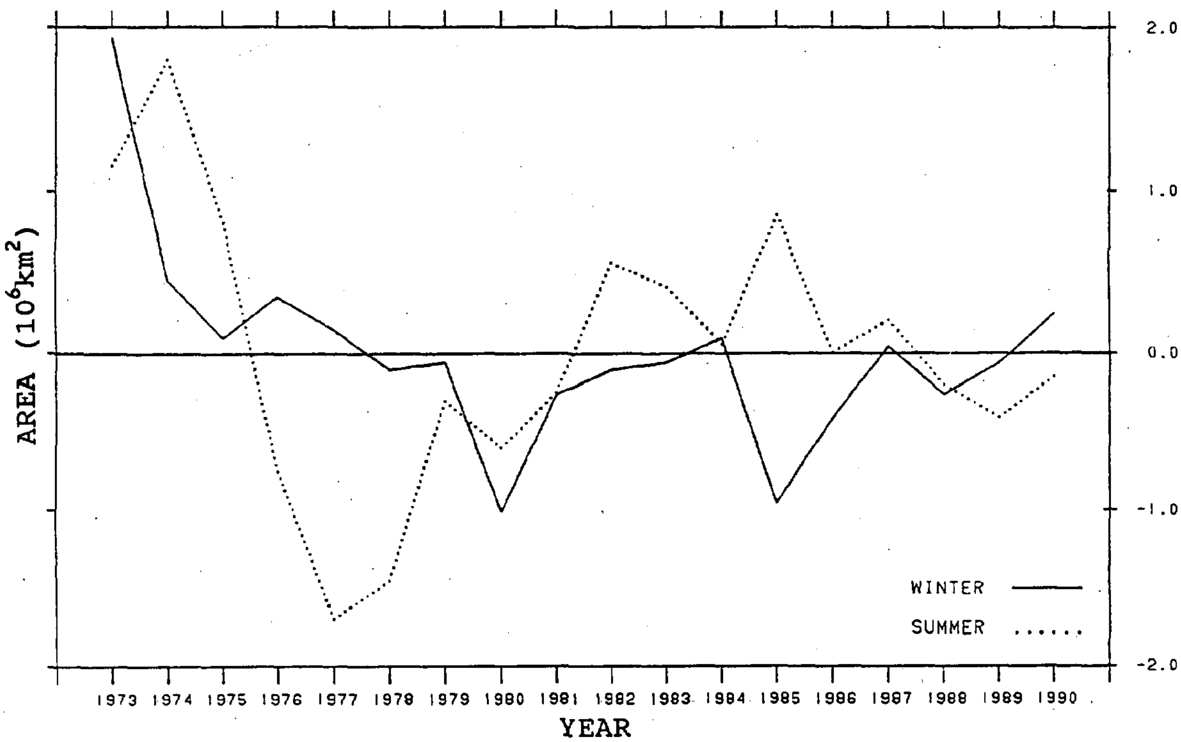


Figure III-2. Time series (1973-90) of the Antarctic sea ice area anomalies for the southern winter (dashed line) which is an average of August and September data and summer (solid line) which is an average of January and February data. Areas are based on satellite remote-sensing data. (Courtesy Climate Analysis Center, NOAA National Weather Center)

SNOW COVER

The extent of snow cover is an important factor in the planetary radiation budget. In addition, measurements of the extent, depth, density, and liquid content of snow are important for determining global precipitation and runoff volumes. Satellite-derived snow cover estimates have been available since the 1960s. These values were not considered suitable for use in scientific analysis until the development of consistent, global-scale analyses in 1973.

The record indicates that the late 1970s were marked by a sequence of years with considerably above-normal snow cover. The 1980s have witnessed less snow cover and a general return to the pre-1970s conditions. The warmer-than-average temperature in the Northern Hemisphere during the 1980s may be linked in part to the variations in snow coverage. Time series of Eurasian snow cover and temperature anomalies provide some evidence for the hypothesis that the two are related (Figure III-3). This time series plot suggests that during the spring and, to a lesser extent summer, snow cover area and temperature anomalies are inversely related . Since positive global temperature anomalies are strongly influenced by the Northern Hemisphere spring temperatures in Eurasia, the extreme temperature anomaly of spring 1990 may have been, in part, related to the reduced snow cover area during spring and summer. No strong relationships between snow cover area and surface temperature anomaly were evident in the time series for the fall and winter seasons.

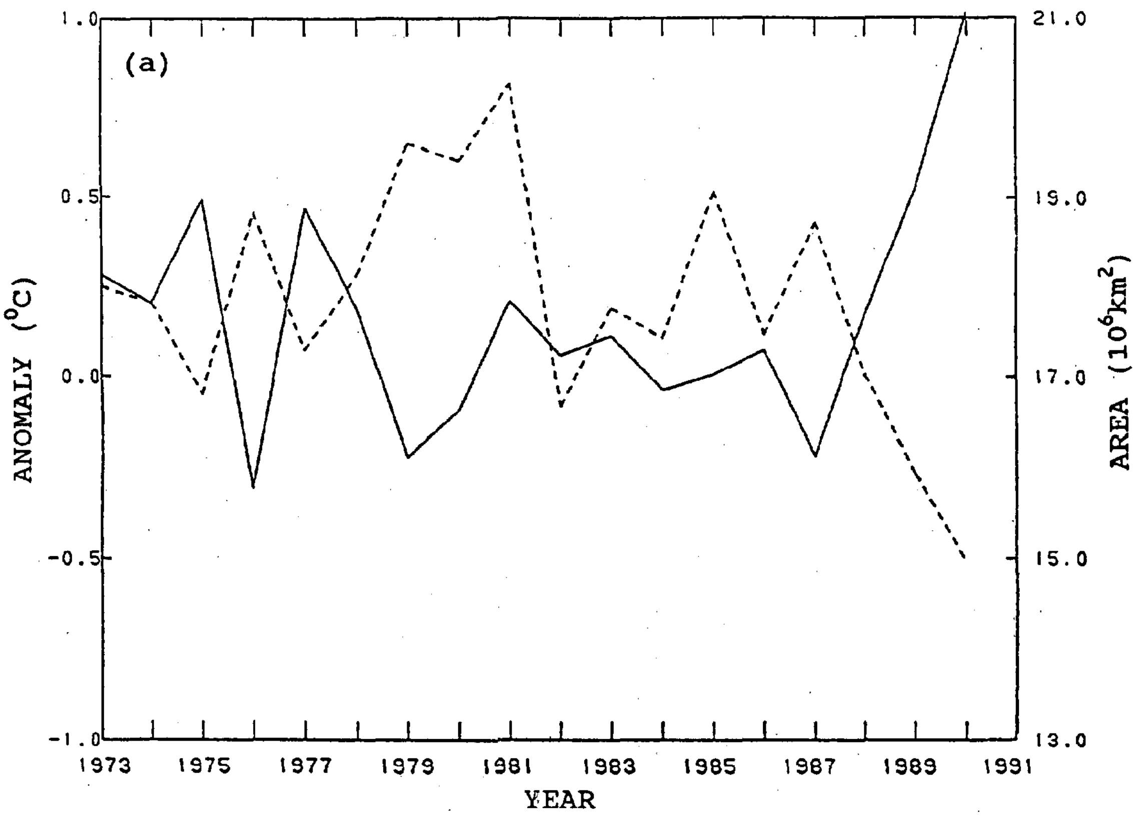


Figure III-3 (a)-(b). Time series (1973-90) of Eurasian snow cover area derived from satellite data (dashed line) and Eurasian temperature anomalies (solid line) derived from an analysis of surface weather stations for (a) spring and (b) summer. The lefthand scale gives the temperature anomaly in degrees Celsius while the righthand scale gives the snow cover in $10^6 km^2$. (Courtesy Climate Analysis Center, NOAA National Weather Service)

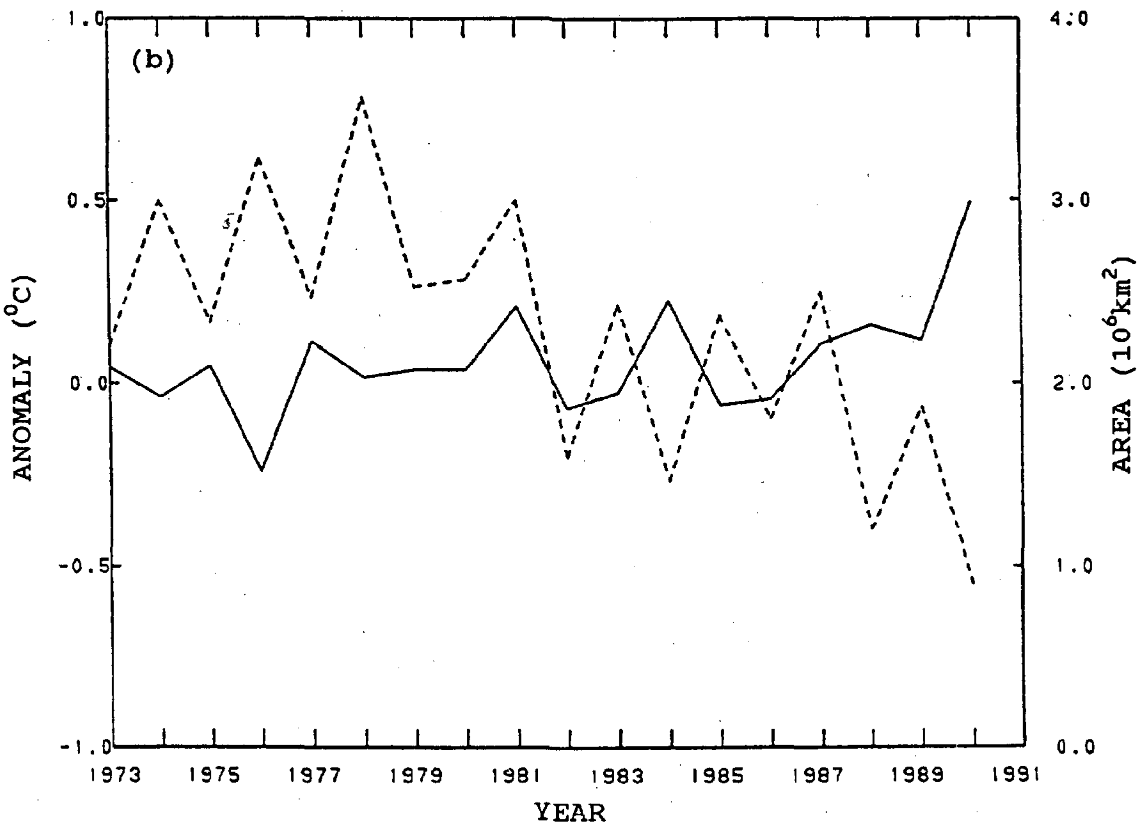


Figure III-3 continued.

IV. BIOSPHERE

Life, since its first appearance billions of years ago, has continually adapted to changes in the Earth's climate. Natural selection has eliminated many species and allowed genetically adaptable life forms to evolve. Not only has life adapted to variations in climate, but the presence of life itself has influenced climate. Natural processes, biological interactions, and, increasingly, human activities have caused changes in the global ecosystem, changes in species abundance, and modification of habitats.

FISHERIES

Fish has become an increasingly important part of the American economy. Our nation's fishery resources support large commercial and recreational fishing industries, providing food, income, employment, and recreation. Commercial landings of fish and shellfish alone have a value of billions of dollars. Most of our fishery resources are products of coastal waters and adjacent estuaries, areas that are increasingly subject to pollution, habitat loss, and overfishing. Two-thirds of the commercial fisheries harvest is estuarine dependent. Regional stocks of the most popular species are declining and species composition, size, and abundance are being changed.

a. Commercial Landings

Commercial landings by U.S. fisherman in 1990 amounted to 9.7 billion pounds (4.4 million metric tons) valued at $3.6 billion, an increase of 1.2 billion pounds (564,900 metric tons) in quantity, and $334.0 million (up 10 percent) in value compared with 1989 (Figure IV-1). Landings of major finfish species such as Atlantic and Pacific cod, Alaska pollock, and flounders increased. Finfish accounted for 86 percent of total landings, but only 55 percent of the total value of finfish and shellfish.

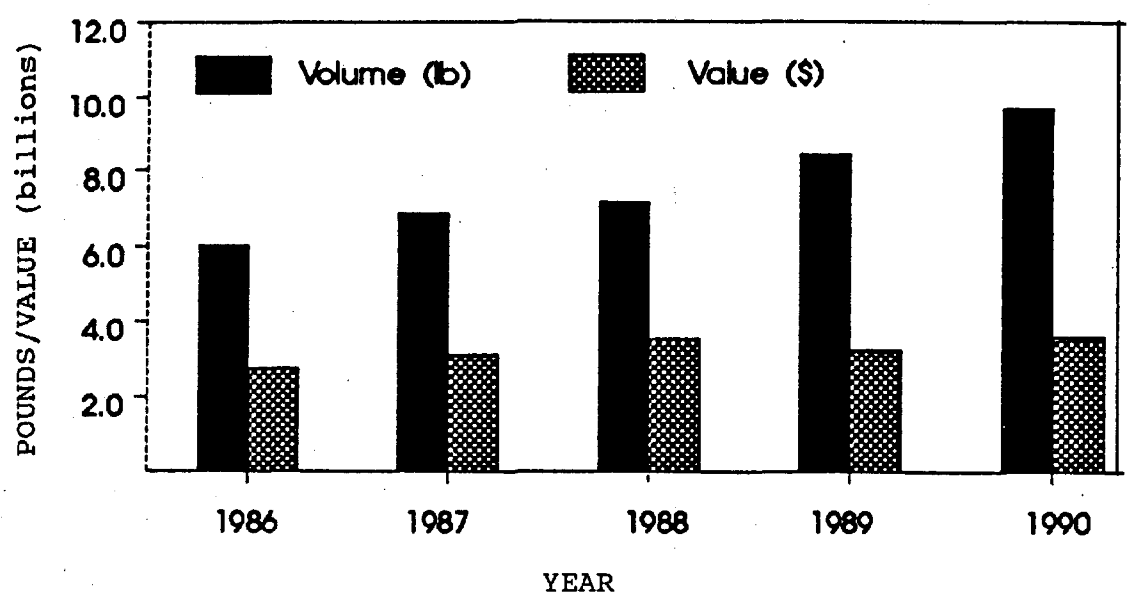


Figure IV-1. U.S. commercial landings (edible and industrial). (Courtesy Fisheries Statistics Division, NOAA National Marine Fisheries Service)

In terms of volume, the top five species caught by commercial fishermen in 1990 were pollock, menhaden, salmon, cod, and flounder (Figure IV-2a). Salmon, shrimp, crab, pollock were the top five species in terms of value (Figure IV-2b). Compared with 1989, landings of clams, crabs, flounders, Alaska pollock, and Atlantic and Pacific cod increased, while shrimp, salmon, and tuna landings decreased.

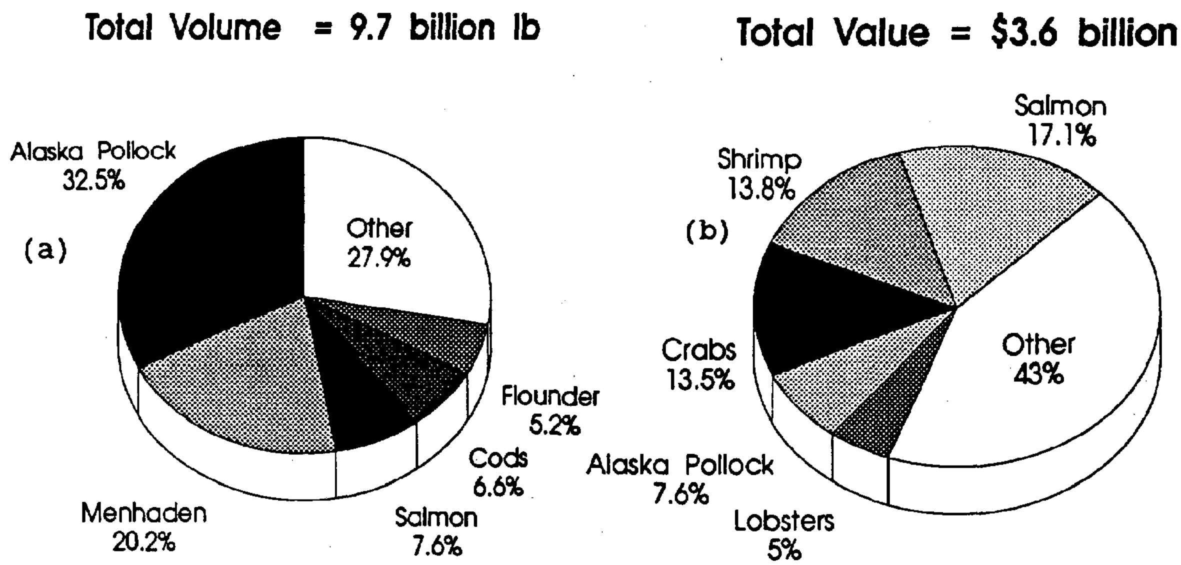


Figure IV-2 (a)-(b). (a) Total volume and (b) total value of the major commercial species caught by U.S. fishermen. (Courtesy Fishery Statistics Division, NOAA National Marine Fisheries Service)

b. Recreational Catch

The U.S. recreational catch in 1990 on the Atlantic and Gulf coasts was an estimated 230.9 million fish. These fish weighed approximately 317.7 million pounds and were taken on an estimated 39.8 million fishing trips (Figure IV-3). Of this amount, 141.5 million pounds (45 percent) were landed, the balance was released.

The five species groups most commonly caught by recreational anglers in 1990 on the Atlantic and Gulf coasts by weight were bluefish, tunas/mackerels, drums/croakers, porgies, and dolphin (Figure IV-4a). The total catch in number on the Pacific coast for 1989, the last year data are available, was estimated to be 41.3 million fish (27.8 million pounds), exclusive of salmon, which historically has been about two percent of the total Pacific recreational catch (Figure IV-4b).

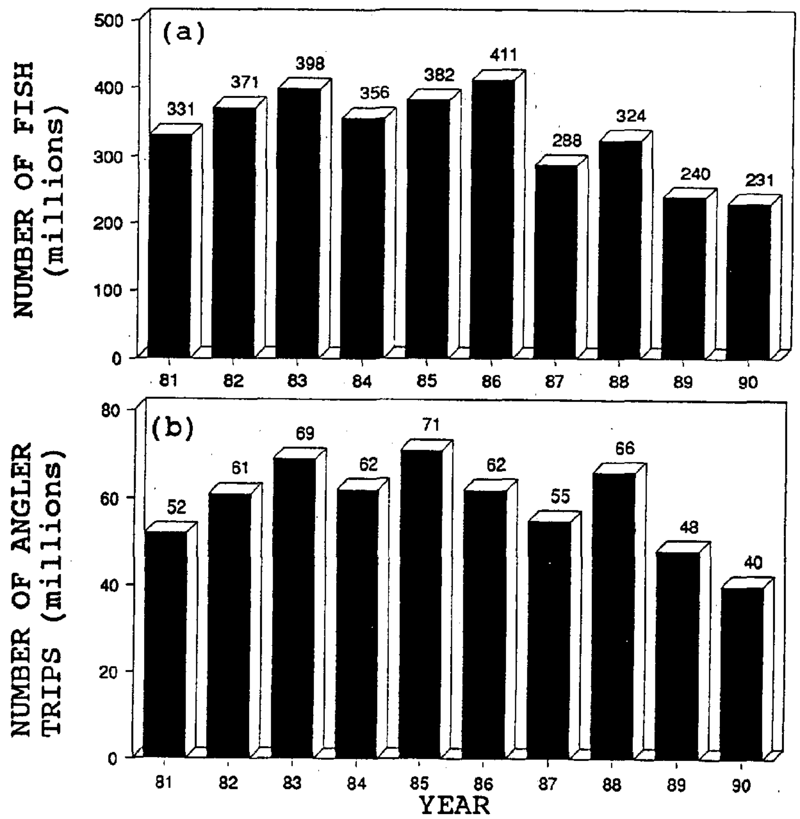


Figure IV-3 (a)-(b). Marine recreational fisheries (a) catch and (b) fishing trips Atlantic and Gulf Coasts, 1981-1990. 1990 data provisional. (Courtesy Fisheries Statistics Division, NOAA National Marine Fisheries Service)

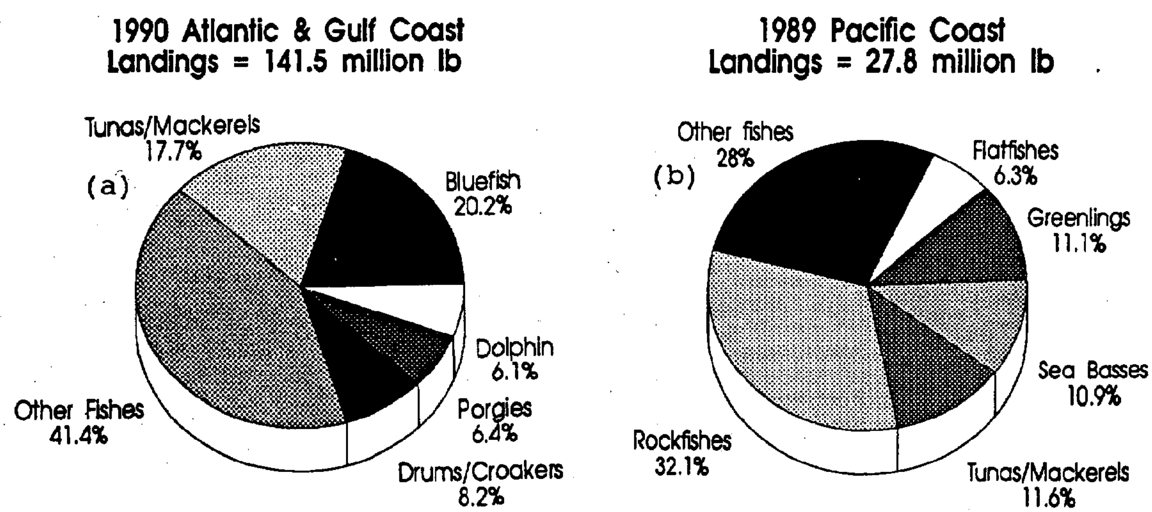


Figure IV-4 (a)-(b). (a) 1990 Atlantic and Gulf of Mexico coast landings and (b) 1989 Pacific coast landings. (Courtesy Fisheries Statistics Division, NOAA National Marine Fisheries Service)

c. Catch in the U.S. EEZ

All fishery resources within the 200-mile Exclusive Economic Zone (EEZ), except highly migratory species of tuna, are subject to management by one or more of the eight Regional Fishery Management Councils created by the Magnuson Fishery Conservation and Management Act (MFCMA) of 1976. The Councils develop Fishery Management Plans (FMPs) for species requiring management. The FMPs are designed to provide for the optimum utilization of the resources, while giving preference to U.S. fishermen over foreign fisherman. The MFCMA led to the development of "joint ventures" in 1979, wherein U.S. commercial fishermen catch and sell to foreign vessels certain species for which U.S. demand is low relative to the abundance of the species.

The combined catch by U.S. and foreign vessels in the EEZ was 6.0 billion pounds (2.7 million metric tons) in 1990 (Figure IV-5), a decrease of 68.4 million pounds (1 %) compared with 1989. The U.S. share was 99 percent of the total. The foreign catch of fish (excluding tunas) and shellfish in the U.S. EEZ was 20.3 million pounds in 1990, a 75 percent decrease compared with 1989. The N. Atlantic U.S. EEZ supplied 100 percent of the total foreign catch.

Joint venture catches in the U.S. EEZ (Figure IV-5) grew from 23.3 million pounds (10.6 thousand metric tons) in 1979 to 3.2 billion pounds (1,452.2 thousand metric tons) in 1988, but in 1990 the catch decreased to 800,600 pounds (363.1 thousand metric tons). The U.S. harvesting and processing capabilities have expanded greatly in the last few years, decreasing the need for these joint venture arrangements.

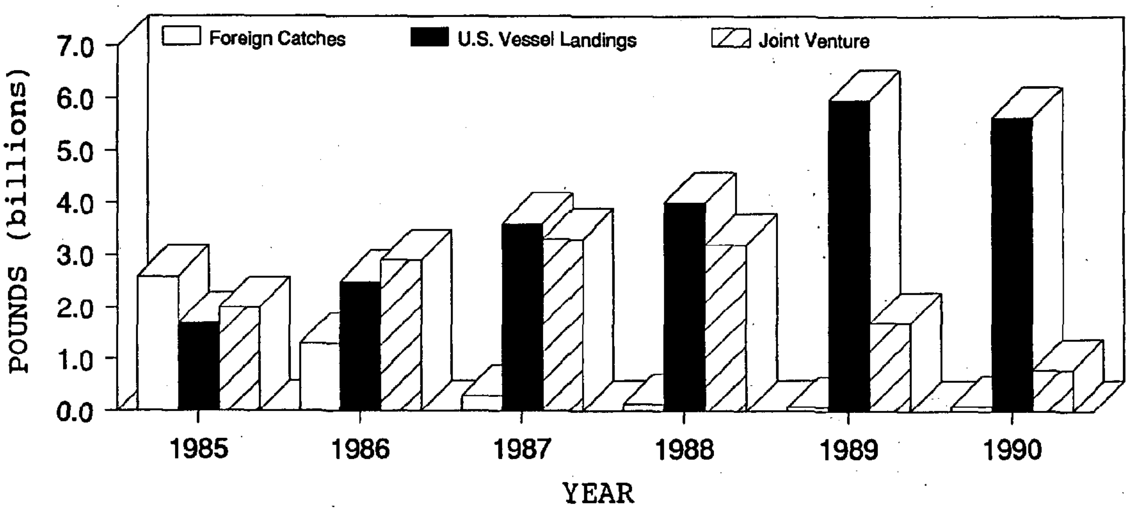


Figure IV-5. U.S., foreign, and joint venture catches in the U.S. EEZ, 1985-1990. (Courtesy Fishery Statistics Division, NOAA National Marine Fisheries Service)

d. World Landings

In 1989, world commercial fishery landings were a record 99.5 million metric tons, an increase of 772,000 metric tons (less than 1 percent) compared with 1988 (Figure IV-6). The USSR was the leading nation with 11 percent of the total catch; China, second with 11 percent, Japan, third with 11 percent; followed by Peru with 7 percent; Chile, fifth with 6 percent; and the United States with 6 percent.

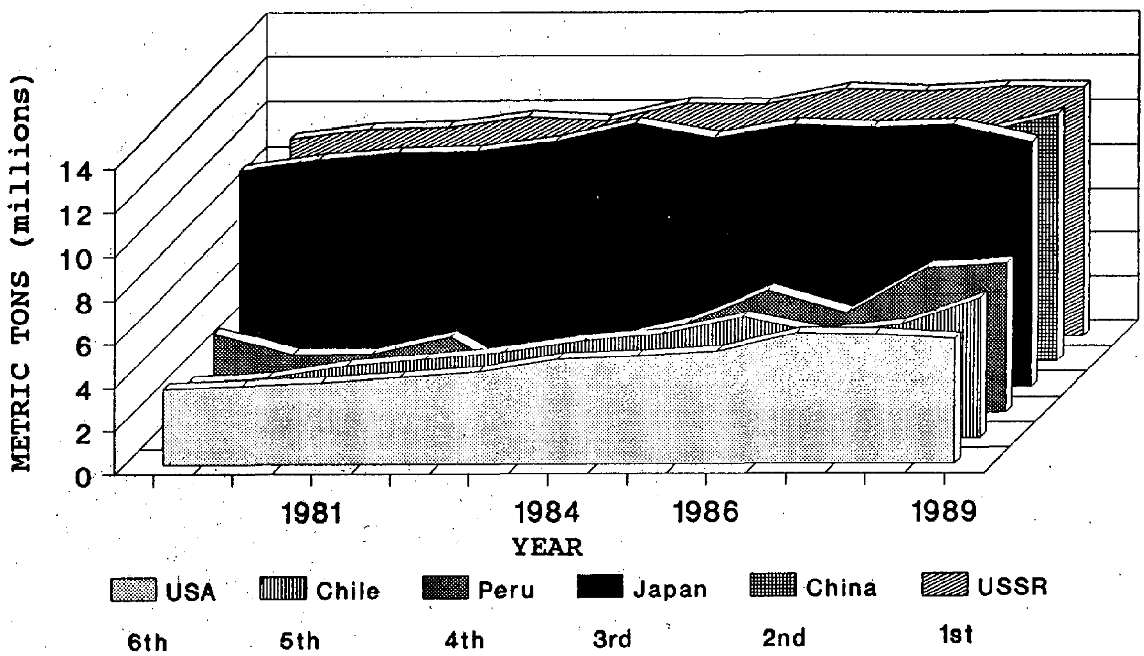


Figure IV-6. World commercial catch by leading countries, 1979-1989. (Courtesy Fishery Statistics Division, NOAA National Marine Fisheries Service)

e. Selected U.S. Fisheries.

i. Reef Fish

Waters of the western Atlantic Ocean, Gulf of Mexico, and Caribbean Sea contain more than 100 species of reef fish that are considered commercially or recreationally important. Fishing pressure has increased greatly, and most traditional reef fisheries are probably fully exploited or overfished. Eight out of the ten major species in the Atlantic fishery show significant declines in average size since 1972. An example is the decline in the weight index of gag (a species of grouper) shown in Figure IV-7. In the Caribbean, traditional mainstays of the fishery such as Nassau grouper have practically disappeared, and the major target species in recent years, e.g., red hind (a grouper), show declines in total landings since the late 1970s. Figure IV-8 shows the dramatic decline in yield of Caribbean reef fish.

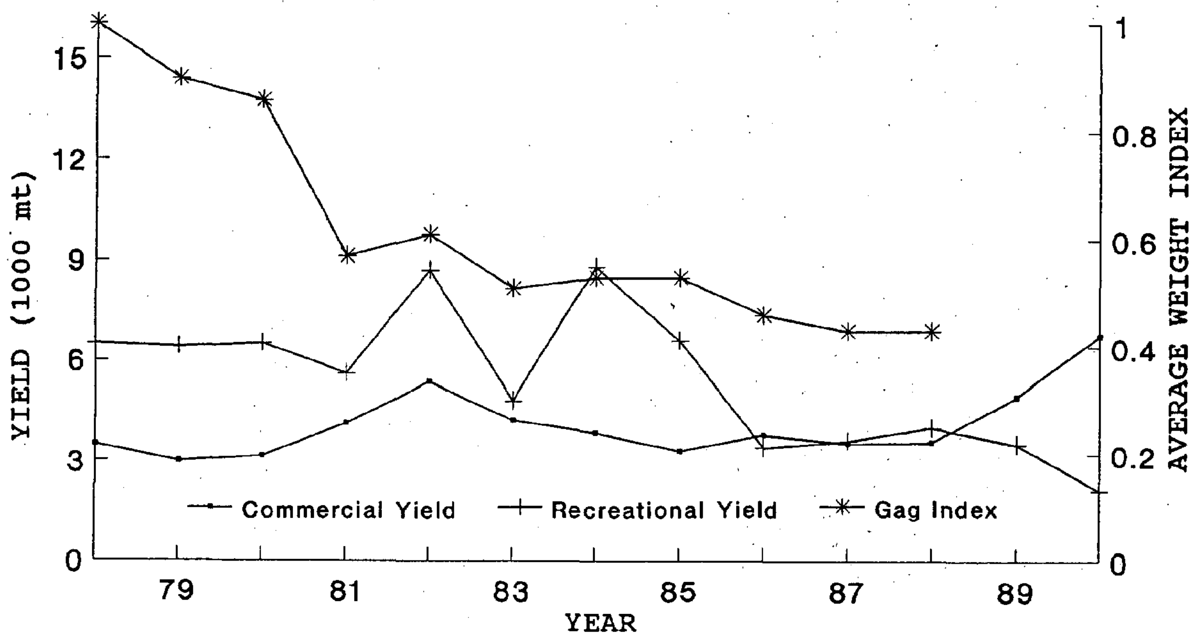


Figure IV-7. Yield of Atlantic reef fish, 1978-1990; weight index of gag. Yield in thousands of metric tons (mt=metric tons). (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

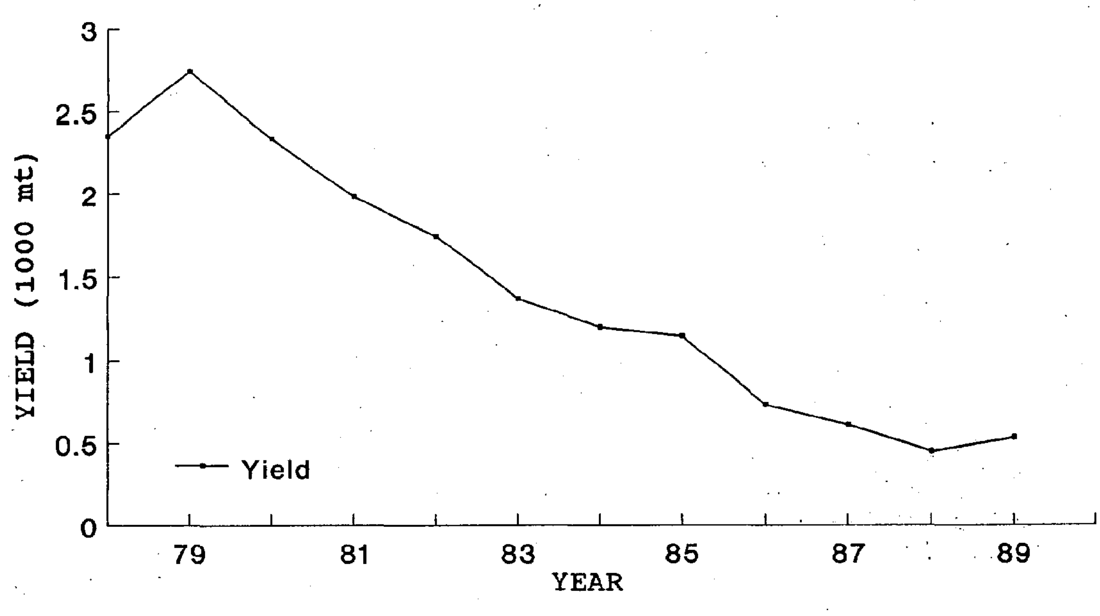


Figure IV-8. Yield of Caribbean reef fish in thousands of metric tons (mt= metric tons), 1978-1989. (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

ii. Oceanic Pelagics

The Atlantic Ocean pelagic fishery (open water) resources, including tunas, swordfish, marlins, and sailfish, are highly migratory species harvested over large geographic regions. The primary species harvested in the U.S. has shifted since 1960 from bluefin tuna to swordfish to yellowfin tuna. In 1961-1973, bluefin tuna represented 45-80 percent of the U.S. western Atlantic yield, but the percentage is now less than 10 percent. This decline in bluefin tuna catch and a similar decline in swordfish catch coincide with declines in abundance (Figure IV-9). In 1961-1983, the percentage of yellowfin tuna in the U.S. catch was generally less than 10 percent, but the United States has become a major harvester of yellowfin tuna, which now comprises 45 percent of the catch.

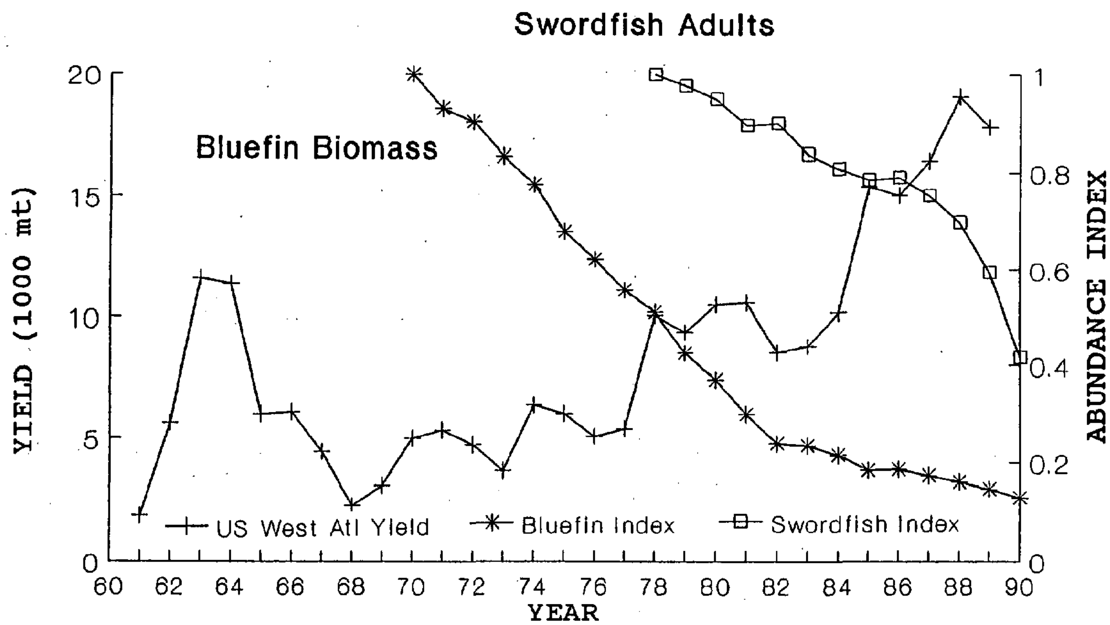


Figure IV-9. Change in abundance of bluefin tuna and swordfish compared to yield of all ocean pelagic species, 1961-1989. Bluefin index is based on biomass; swordfish index is based on number of adults. Yield in thousands of metric tons (mt=metric tons). (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

iii. Sharks

A substantial recreational fishery and directed commercial shark fishery for coastal sharks occur in the U.S. Atlantic. Pelagic sharks are targeted by shark tournaments and are a major bycatch of the longline fishery for swordfish and tuna. Since 1970, shark meat has become a popular seafood. Very recently, however, high levels of mercury were discovered in shark flesh, and this may render the market unstable. Sharks are vulnerable to overfishing because of low reproductive potential and slow growth rates. Both recreational and commercial fishermen have recently voiced concern regarding a perceived downward trend in shark availability. Figure IV-10 shows trends in recreational and commercial yields. A fishery management plan is expected to become effective in 1992.

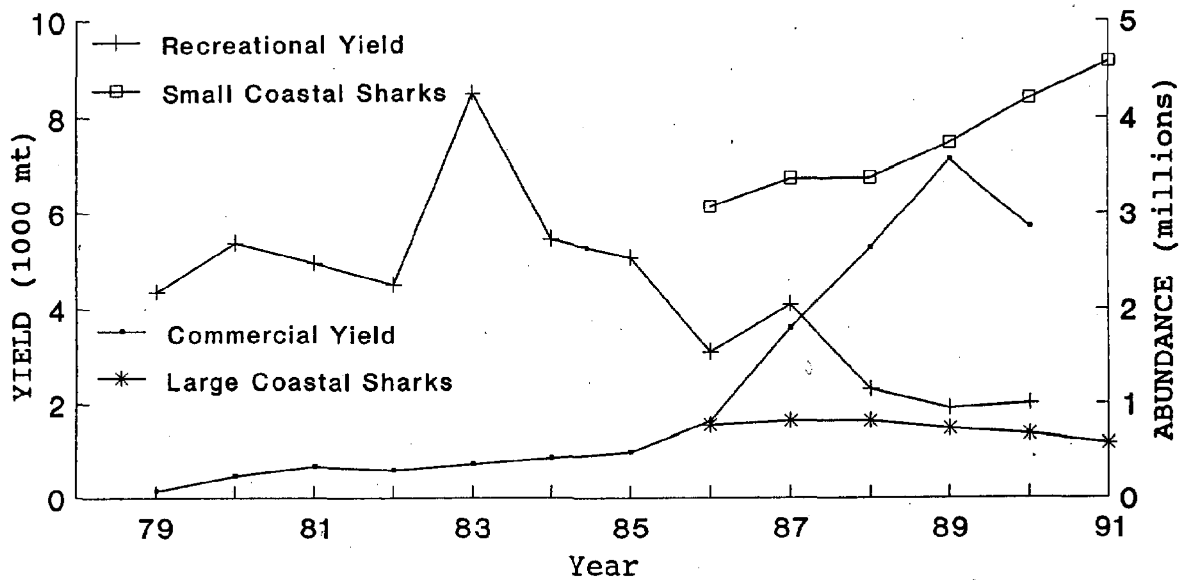


Figure IV-10. Recreational and commercial yields of Atlantic sharks; abundance estimates of large and small coastal sharks. Yield in thousands of metric tons (mt=metric tons). (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

iv. Menhaden

Menhaden are filter feeders found in coastal and estuarine waters. Two species, the Atlantic and Gulf menhaden, form surface schools that support a large industrial fishery producing fish meal, oil, and solubles. By weight landed, menhaden is the largest fishery in the United States. Figure IV-11 shows the trends in yield and biomass since 1950. The Atlantic menhaden stock is overutilized. Landings have improved since a collapse of the stock in the 1960s, but not to the levels of the late 1950s. The Gulf menhaden stock is fully utilized. Historically, Gulf landings rose from the beginning of the fishery to a peak in 1984, but they have declined steeply since 1987.

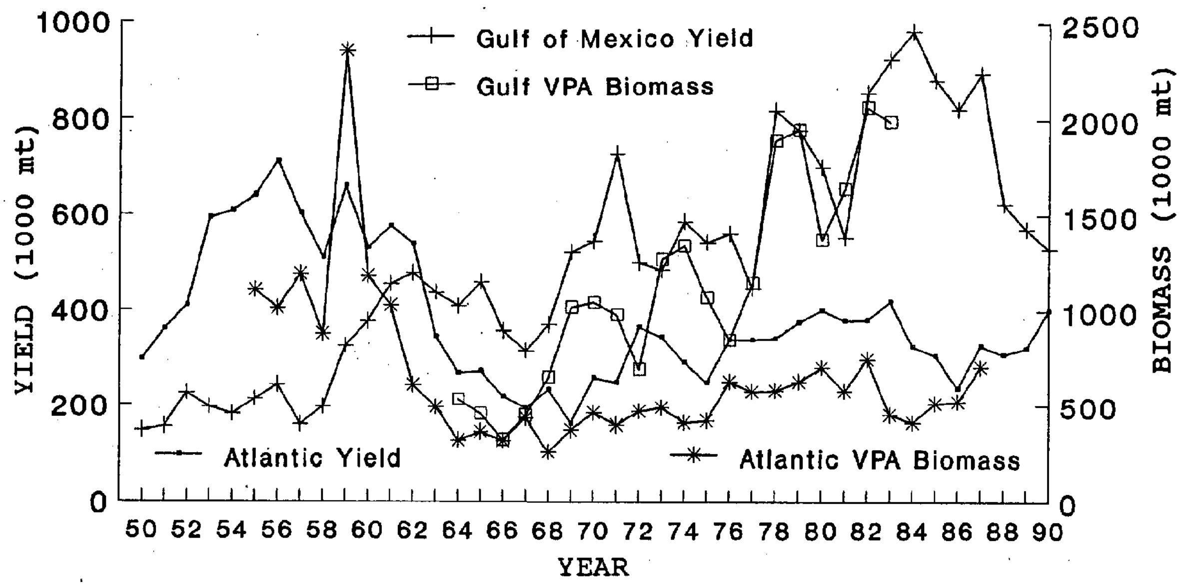


Figure IV-11. Yield and biomass of Gulf and Atlantic menhaden in thousands of metric tons (mt=metric tons), 1950-1990. VPA = virtual population analysis. (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

v. Shrimp

Gulf of Mexico shrimp fishery trends for the past 30 years indicate that both brown and white shrimp catch levels have significantly increased, while pink shrimp catch, which was very stable until about 1985, has declined the past few seasons and is now at an all-time low (Figure IV-12). Recruitment levels for each of the species have generally showed the same trends as catch. There has been a significant increase in the number of recruits produced per parent for brown shrimp, but no significant increase is seen for white and pink shrimp. Shrimp fisheries are affected by changes in estuarine conditions. The increase for brown shrimp appears to be related to alterations in marsh habitat. Coastal subsidence and sea level rise in the northwestern Gulf of Mexico are causing intertidal marshes to be inundated longer and become more favorable for production of food for shrimp. Subsidence also has increased accessibility by creating more marsh edge, expanded the estuarine-area by saltwater intrusion, and provided more protection from predation. As a result, the nursery function of these marshes has been greatly magnified, resulting in an expansion in recruitment to the brown shrimp fishery. Since continued subsidence will lead to marsh deterioration and ultimate loss of supporting wetlands, current high fishery yields may not be indefinitely sustainable.

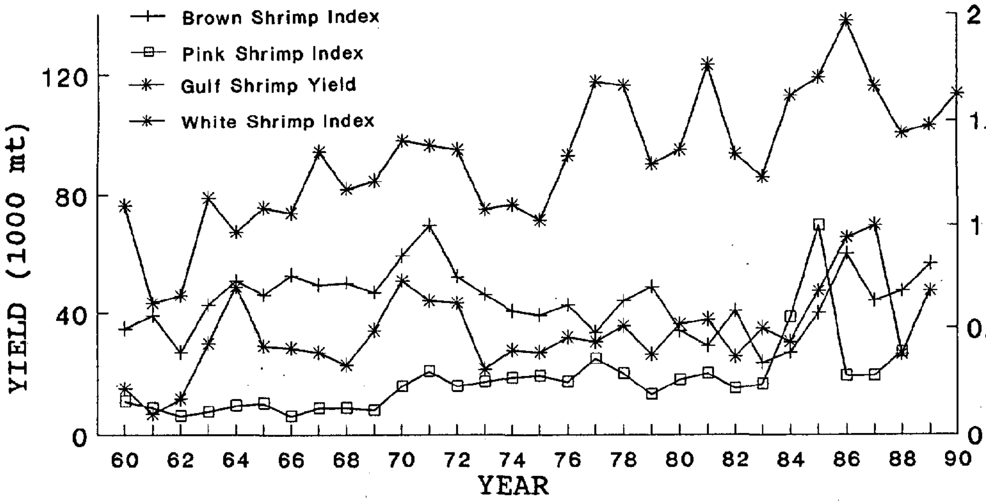


Figure IV-12. Gulf of Mexico shrimp yields since 1960. Yield in thousands of metric tons (mt=metric tons). (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

vi. Groundfish and Flounders

This group of fish includes important gadoid species of the northeast United States (Atlantic cod, haddock, redfish, silver and red hake, and pollock) and several flatfish (yellowtail flounder, summer and winter flounder, American plaice, witch flounder, and windowpane). The combined index for this group declined by almost 70 percent between 1963 and 1974, reflecting substantial increases in exploitation associated with the advent of distant-water fleets (Figure IV-13). By 1974, indices of abundance for many of these species had dropped to the lowest levels observed in the history of the survey time series. Partial resource recovery occurred during the mid- to late 1970s attributed to reduced fishing effort associated with increasingly restrictive management. The aggregate index peaked in 1978 and subsequently declined in 1987-1988 to the lowest values in the time series. The index has since increased somewhat reflecting improved recruitment for some species.

vii. Atlantic Herring and Mackerel

Abundance of northeast U.S. Atlantic herring and Atlantic mackerel has been monitored using spring survey data. This index declined to minimal levels in the mid-1970s, reflecting pronounced declined in abundance for both herring and mackerel (including the collapse of the Georges Bank herring stock). This has been followed by an increasing trend in recent years; index values for 1987-90 are among the highest observed in the series, reflecting high levels of abundance for both species (Figure IV-14).

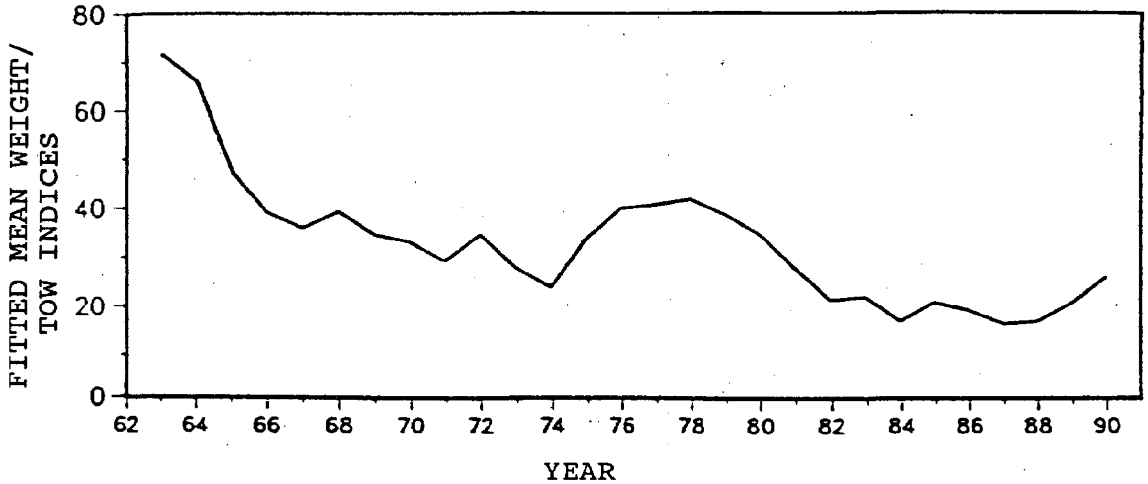


Figure IV-13. Trends in the index of aggregate abundance (catch in weight per survey trawl haul) for northeast United States groundfish and flounders, 1962-1990. (Courtesy Northeast Fisheries Science Center, NOAA National Marine Fisheries Service)

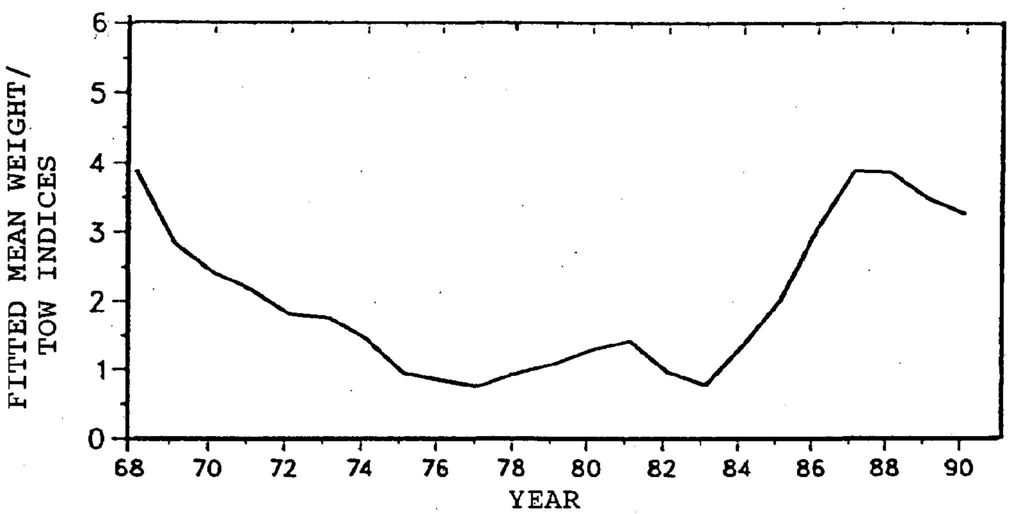


Figure IV-14. Trends in the index of aggregate abundance (catch in weight per survey trawl haul) for Atlantic herring and Atlantic mackerel, 1968-1990. (Courtesy Northeast Fisheries Science Center, NOAA National Marine Fisheries Service

viii. Skates and Spiny Dogfish

Spiny dogfish and skates are two important fishery resource components of the northeast United States which are effectively monitored using spring survey data (Figure IV-15). Spiny dogfish and seven skate species are included in the index. The continued increase in this index since the late 1960s reflects major changes in relative abundance within the finfish species complex, with increasing abundance of species of low commercial value. Survey catches of both dogfish and skates since 1986 have been the highest observed in the time series. These increases in dogfish and skate abundance, in conjunction with declining abundance of groundfish and flounders (Figure IV-13), have resulted in the proportion of dogfish and skates in Georges Bank survey catches increasing 25 percent by weight in 1963 to nearly 75 percent in recent years.

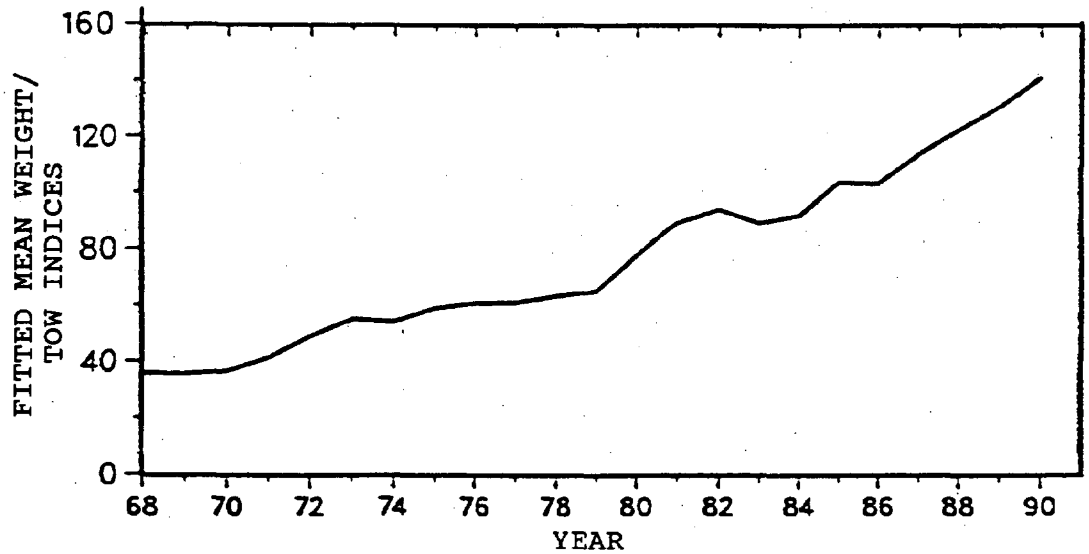


Figure IV-15. Trends in the index of aggregate abundance (catch in weight per survey trawl haul) for skates and spiny dogfish, 1968-1990. (Courtesy Northeast Fisheries Science Center, NOAA National Marine Fisheries Service)

ix. Northern Anchovy

Northern anchovies are small (< 7 inches), short-lived (to 4 years) plankton eaters that typically school near the surface in waters of 12^{o}-22^{o}C. The species ranges from British Columbia to Baja California. An important Pacific coast fishery, it is used for food, bait, and industrial fish products. The species is also important forage for marine fishes, mammals, and birds. A "central subpopulation," which supports United States fisheries ranges along the California coast. Northern anchovy biomass (Figure IV-16) in the central subpopulation averaged 400,000 metric tons (mt) during 1964-70, increased rapidly to 1,800,000 mt in 1974, and then declined to 490,000 mt in 1978. Although total anchovy harvests since 1983 have been less than the theoretical maximum sustainable yield and the historical levels before 1983, abundance continues to decline slowly. As a final safeguard against depletion the species is under a fishery management plan.

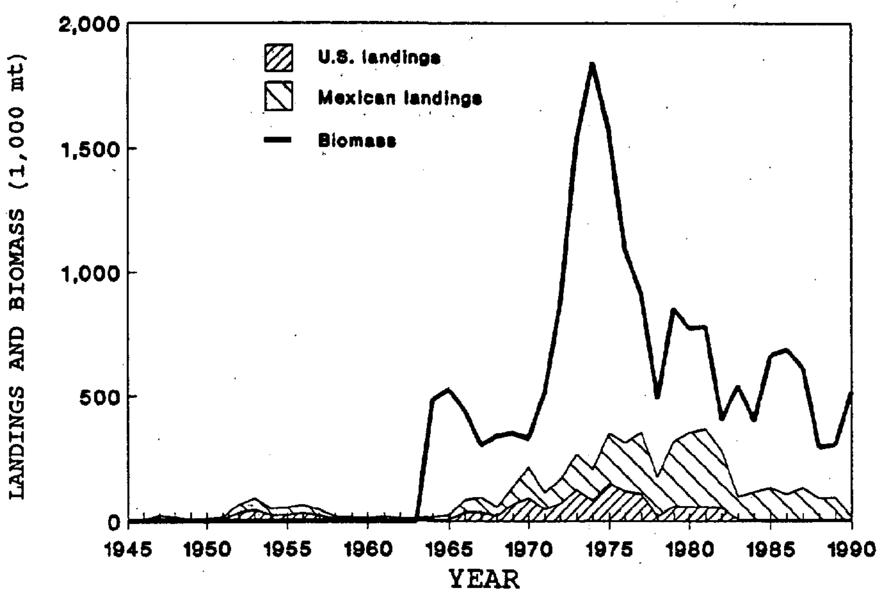


Figure IV-16. Northern anchovy landings by United States and Mexican fleets during 1945-90, and biomass (age 1 or older) from 1964 to 1990. Values in thousands of metric tons (mt=metric tons). (Courtesy Assistant Administrator for Fisheries, NOAA National Marine Fisheries Service)

x. Pacific Halibut

Pacific halibut has been fished commercially since the late 1800s; it is now fished only with longline gear, though other gear types accidentally catch some halibut. There is also an active recreational fishery as well. Halibut is found from the Bering Sea to Oregon, though the center of abundance is in the Gulf of Alaska. In 1990, nearly 37,000 metric tons (mt) of Pacific halibut were landed commercially (31,900 mt in the United States and 5,100 mt in Canada) (Figure IV-17) valued at $115 million. Halibut stocks are assessed annually, and the fishable population apparently peaked at 166,000 mt in 1986-87 after a rebuilding period (Figure IV-17). The population has since declined at about 5 percent per year. Some decline is still expected, but halibut numbers remain fairly high by historical standards.

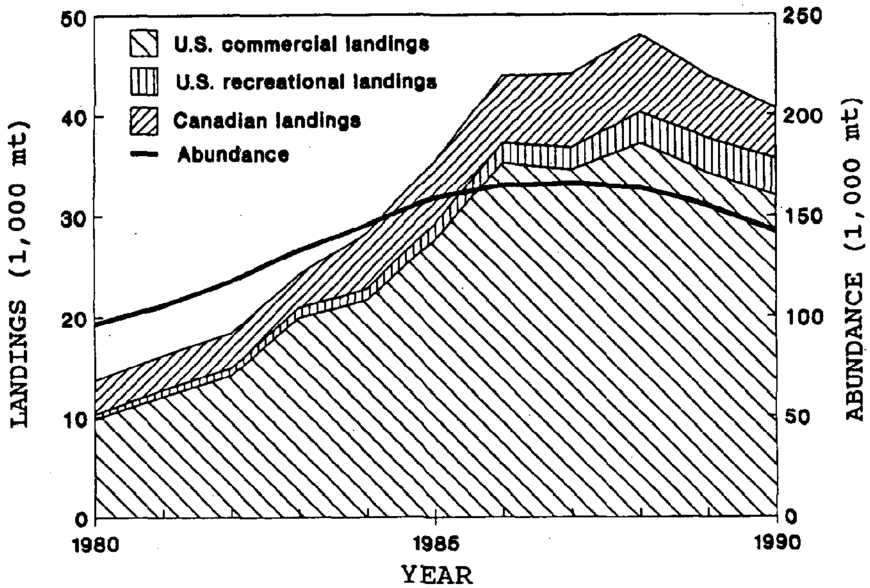


Figure IV-17. Landings and abundance trends for Pacific halibut in the north Pacific for United States commercial and recreational fisheries and the Canadian fishery, 1980-90. Values in thousands of metric tons (mt=metric tons). (Courtesy Assistant Administrator for Fisheries, NOAA National Marine Fisheries Service)

xi. Bering Sea-Aleutian Islands Groundfish

The average eastern Bering Sea-Aleutian Islands groundfish catch during 1988-90 was about 1.8 million metric tons (mt) (Figure IV-18) valued at about $352 million in 1990. The dominate groups harvested were walleye pollock, 75 percent; flatfishes, 15 percent; Pacific cod, 7 percent; Atka mackerel, 1.4 percent; rockfishes, 0.4 percent; and sablefish, 0.3 percent. Walleye pollock produced the largest single-species catch in the United States (about 1.4 million mt) valued at $255 million in 1990. Bering Sea-Aleutian Islands groundfish populations have been maintained at high levels under the MFCMA (Figure IV-18).

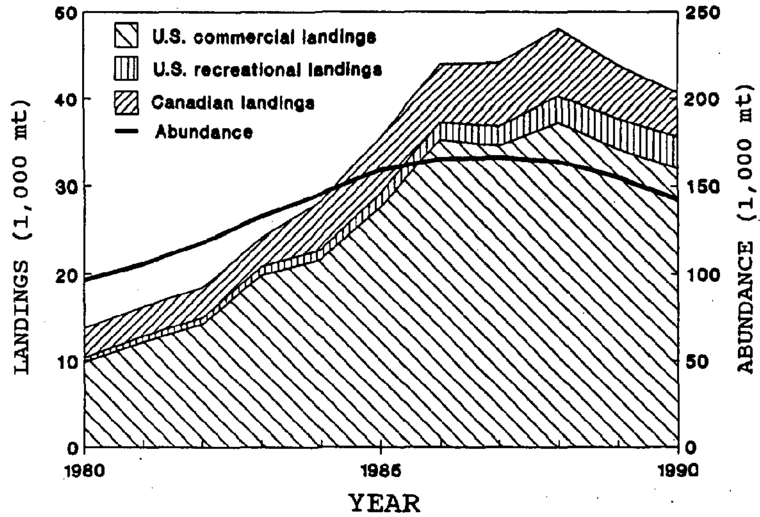


Figure IV-18. Landings and abundance trends for groundfish resources in the Bering Sea-Aleutian Islands region for the foreign, joint-venture, and U.S. fisheries, 1976-90. Values in thousands of metric tons (mt=metric tons). (Courtesy Assistant Administrator for Fisheries, NOAA National Marine Fisheries Service)

ZOOPLANKTON

Zooplankton are small marine animals that feed on phytoplankton or on other zooplankton. They range in size from about 20 microns (microzooplankton) to 5000 microns (megaplankton). Some are abundant (e.g., copepods) and form important links in pelagic food webs between phytoplankton and larger animals. Most zooplankton are composed of protozoans, small crustaceans (e.g., copepods), and the larval stages of marine invertebrates. The largest zooplankton, the megaplankton, consist of chaetognaths (arrowworms), euphausiaceans (krill), small coelenterates (jellyfish), ctenophores (comb jellies), and ichthyoplankton (fish larvae).

It has been suggested that zooplankton can be used to assess trends in climate. Temperature has an effect on the size of zooplankton, with animals growing larger at colder temperature. Changes in mean temperature can result in differences in the stage of development of a population, and in the size of the animals in the population on any given sampling date. Zooplankton biomass and water column temperature and structure have been used successfully for detecting changes in the states of large marine ecosystems and fisheries yields. Two large marine ecosystems, the northeast U.S. continental shelf ecosystem and the California Current ecosystem, have been studied for several decades by NOAA scientists to assess the biogeography, annual cycles, and long-term variation in the distribution, abundance, and composition of plankton.

a. Copepods

Copepods are small crustaceans, most ranging from less than one millimeter (mm) to several mm in length. Marine copepods exist in enormous numbers, and since most copepod species feed on phytoplankton, they are the principal link between phytoplankton and higher trophic levels in many marine food chains. A major part of the diet of many marine animals is composed of copepods.

From 1961 through 1974 the Oceanographic Laboratory in Edinburgh, Scotland conducted monthly monitoring of the zooplankton (including copepods) and larger phytoplankton in the Gulf of Maine using the Hardy Continuous Plankton Recorder (CPR). In 1972, the NOAA National Marine Fisheries Service/Northeast Fisheries Center began a program of cooperation with the Oceanographic Laboratory for the extension of the long-term CPR survey into the additional areas of the western north Atlantic. These measurements are made to monitor changes in the state of the Northeast Shelf Ecosystem in relation to possible effects on the long-term sustainability of fishery yields of the ecosystem. The year 1990 marks the thirtieth since sampling began on the Gulf of Maine, and the twentieth on the Middle Atlantic Bight transects.

The standardized abundances of the copepod Calanus finmarchicus in the Gulf of Maine and the Middle Atlantic Bight are shown in Figure IV-19. C. finmarchicus showed a positive trend in all Gulf of Maine subareas exclusive of Massachusetts Bay beginning in approximately 1979. Values for the Middle Atlantic Bight show a later-occurring positive trend. For 1990, total copepods averaged more than 150 percent and 200 percent above the base value for the whole transects for the Gulf of Maine and Middle Atlantic Bight respectively. Total copepod abundance in the Gulf of Maine for 1990 was the highest in the last 11 years.

b. Ichthyoplankton

Since 1950, trends in the abundance of the larvae of 6 fish stocks, 10 m depth temperature, and zooplankton have been monitored in the California Current by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys (Figure IV-20). This joint program between NOAA and the University of California (Scripps Institution of Oceanography) has monitored the fish stocks, their forage (zooplankton), and the physical characteristics of the ocean environment off california for over 40 years. The larval data are used by fishery managers of the National Marine Fisheries Service to estimate biomass of stocks and the entire CalCOFI data set is widely used by scientists to study the effects of changes in ocean climate on natural resources.

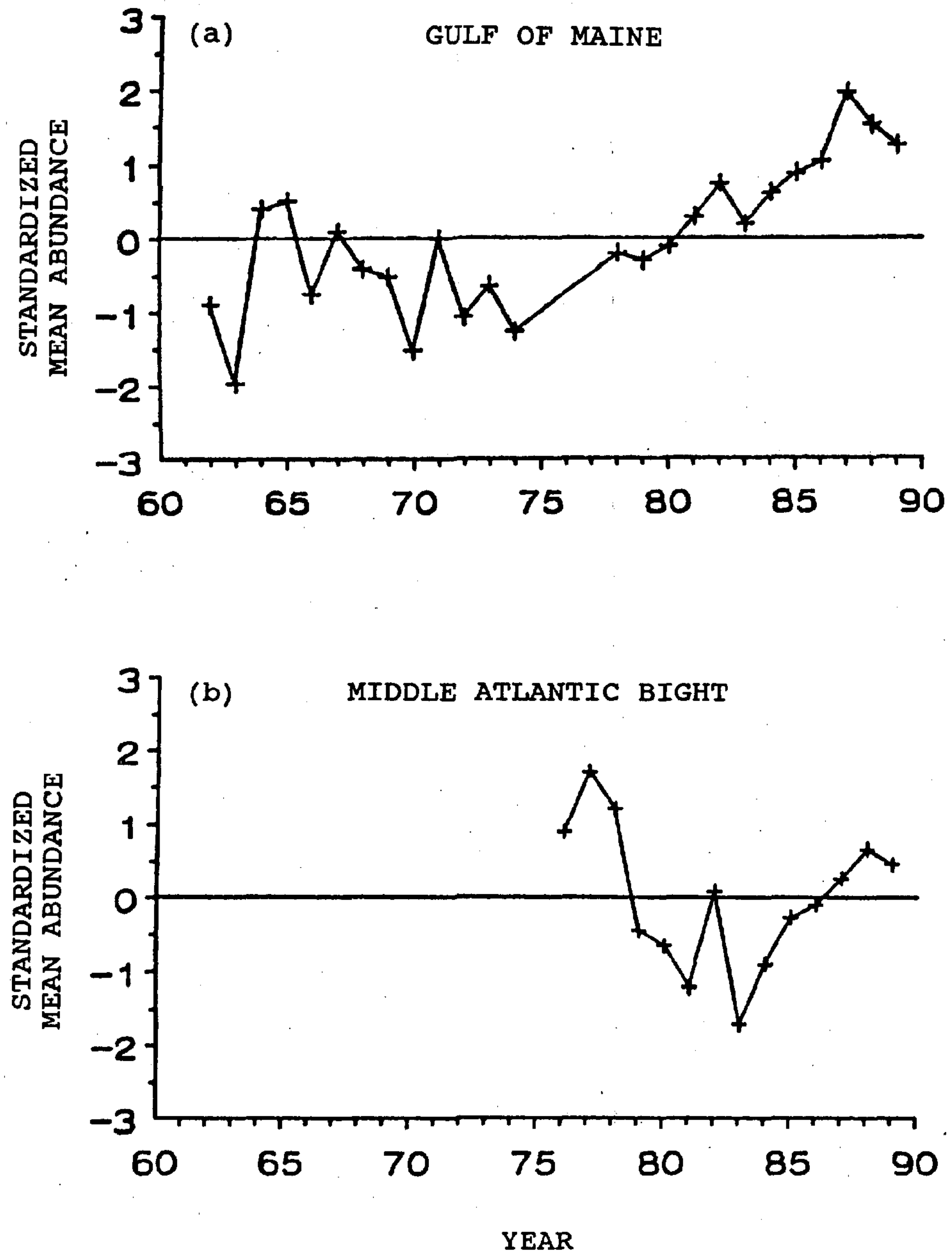


Figure IV-19 (a)-(b). Calanus finmarchicus (Crustacea;Copepoda) in (a) the Gulf of Maine (1961-1989) and (b) Middle Atlantic Bight (1976-1989). Plotted values are annual logarithmic mean abundances, standardized to a zero mean and a unit standard deviation. (Courtesy Kenneth Sherman and Jack Jossi, Northeast Fisheries Science Center, NOAA National Marine Fisheries Service)

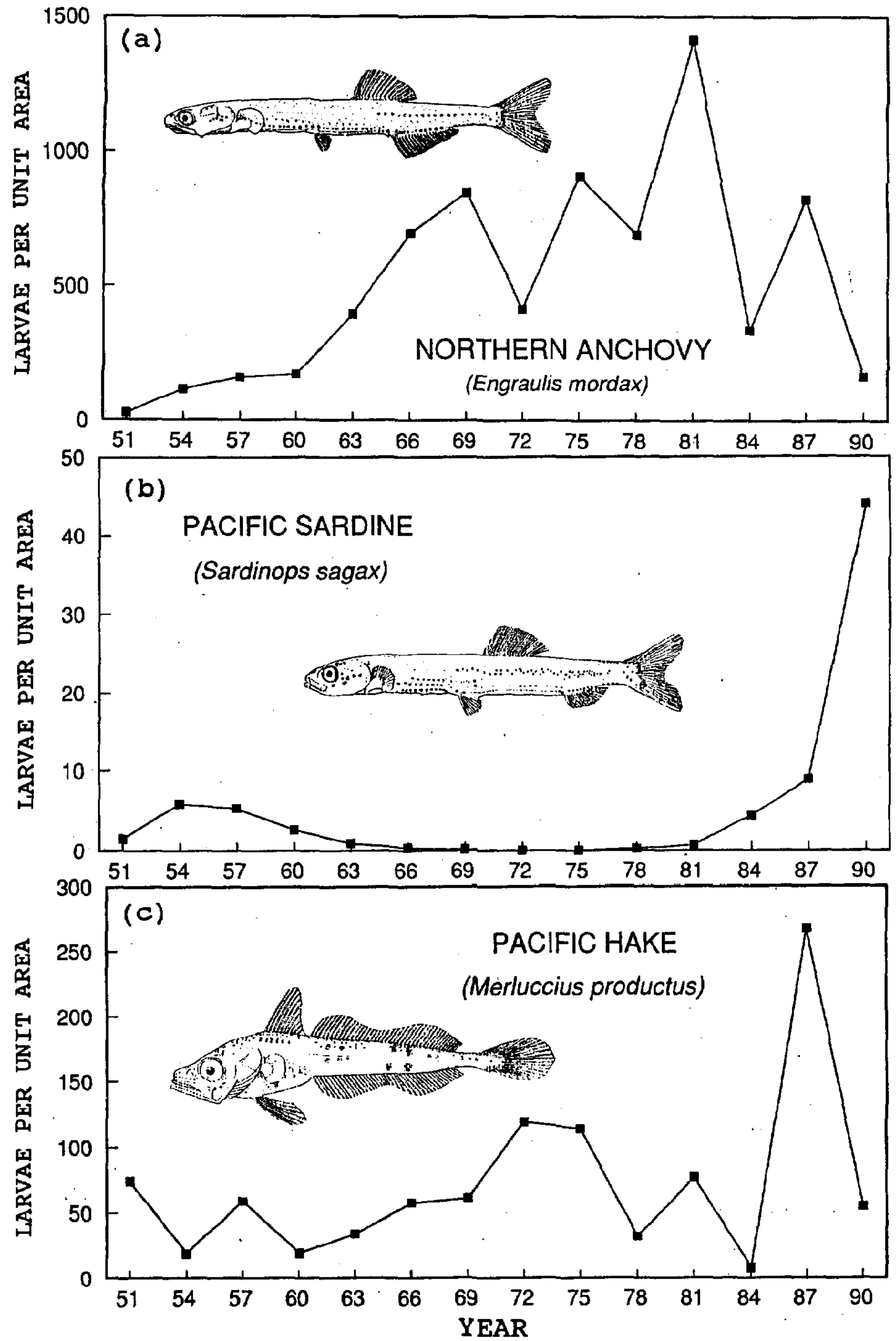


Figure IV-20 (a)-(c). CalCOFI time series of fish larvae abundance for important California commercial fish species, (a) northern anchovy, (b) Pacific sardine, (c) Pacific hake. (Courtesy John R. Hunter, Southwest Fisheries Science Center, NOAA National Marine Fisheries Service)

The scientific accomplishments of the CalCOFI program have had a major influence on fishery and environmental science. Four broad themes can be identified: time series analysis of the environment and fish stocks, hypothesis testing for recruitment mechanisms, development of novel stock assessment models, and fishery management plans. The anchovy management plan is a major practical accomplishment of the CalCOFI program. It is one of the few plans in the world using a long time series of fishery-independent biomass and environmental information. Methods, developed by CalCOFI, are now being widely applied worldwide.

SHELLFISH

Bivalve mollusks such as oysters, clams, and mussels are predominantly found near shore and in estuaries where freshwater mixes with ocean waters. Since colonial times shellfish have provided an important source of food and an economic wealth for many coastal communities. Since shellfish filter large volumes of water, they sometimes accumulate pathogens and contaminants in their tissues. As many shellfish are traditionally eaten raw, contaminated products could be a significant public health problem. Because of their coastal locations, shellfish beds are under state jurisdiction. States place shellfish waters in 5 classifications based on sanitary surveys. Classification of shellfish growing waters is based on the presence of actual or potential pollution sources and levels of coliform bacteria in surface waters.

The National Shellfish Register of Classified Estuarine Waters is produced by NOAA. Previous inventories of the National Shellfish Register have been conducted in 1966, 1971, 1974, 1980, and 1985. The 1990 inventory includes a field survey of classified shellfish waters in 24 states. The survey quantifies the changes since 1985, identifies the reasons for the changes, and lists the sources of pollution affecting harvest-limited waters. Table IV-1 presents regional acres and percentage in shellfish bed closures. Trends in prohibited acreage are shown in Figure IV-21.

Table IV-1. Shellfish bed closures for the United States by region, 1966-1990. Thousands of prohibited acres and percentage of national total prohibited. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)

	Northeast		Southeast		Gulf of Mexico		Pacific	
Year	Area	Percent	Area	Percent	Area	Percent	Area	Percent
1966	443	25	790	45	524	30	3	0.2
1971	710	21	1,702	51	592	18	317	10
1974	711	19	1,897	50	829	17	317	8
1980	782	27	878	31	889	31	318	11
1985	709	23	612	19	1,649	39	318	5
1990	1,020	24	630	15	2,405	56	183	4

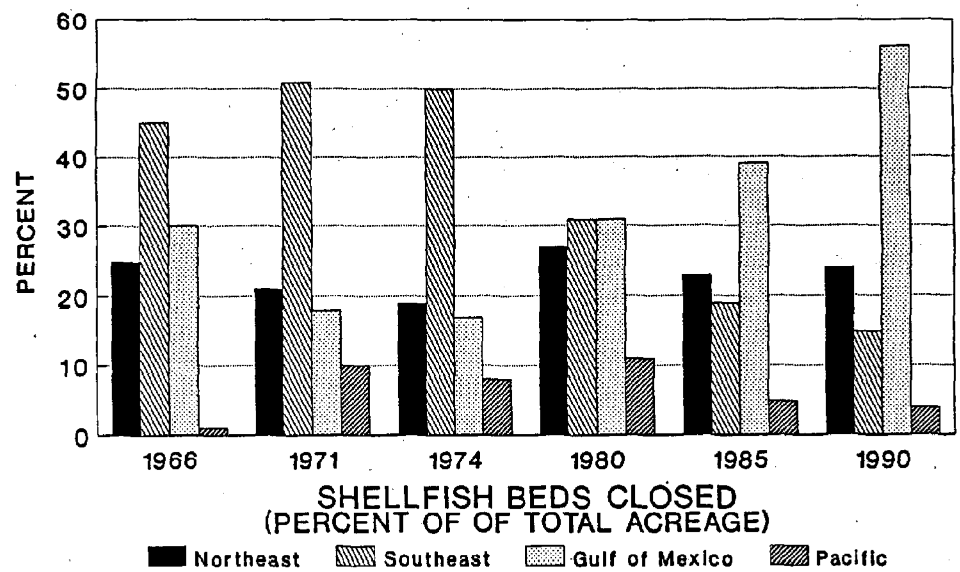


Figure IV-21. Shellfish bed closures for the United States by region, 1966-1990. Percentage of national total acreage prohibited. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)

CONTAMINANTS

Chemical analyses of bottom sediments and selected organisms have been used to gauge the extent to which the marine environment has been affected by human activities. Since 1984, the NOAA Office of Ocean Resources Conservation and Assessment has monitored, through its National Status and Trends (NS&T) Program for Marine Environmental Quality, the concentrations of 70^{+} organic compounds and trace metals in bottom-feeding fish, shellfish, and sediments at U.S. coastal and estuarine locations nationwide. The objectives of the NS&T Program are to monitor the long-term trends of chemical contamination and to assess the effects of human activities on coastal and estuarine areas throughout U.S. coastal waters.

The NS&T Program has seven major programmatic components: the Mussel Watch Project, the Benthic Surveillance Project (these two components provide the majority of chemical contaminant monitoring), Bioeffects Surveys, Historical Trends, Coastal Contamination Assessments, and Specimen Banking. Scientists from the Mussel Watch and Benthic Surveillance Projects collect samples of sediment, fish livers, and bivalve molluscan tissues from more than 300 sites nationwide. Mussel Watch Project samples are collected and laboratory analyses are performed, under contract, by Battelle Memorial Institute's laboratories in Duxbury, MA, and Sequim, WA, for sites on the east coast, west coast, and Hawaii;

and by the Geochemical and Environmental Research Group of Texas A&M University for the Gulf of Mexico sites. Benthic Surveillance Project samples are collected and laboratory analyses are performed, under cooperative agreement, with NOAA's National Marine Fisheries Service laboratories at Seattle, WA, and Beaufort, NC. NS&T samples are analyzed to determine levels of synthetic chlorinated compounds (DDT, its breakdown products, and 9 other pesticides), polychlorinated biphenyls (20 PCBs), polycyclic aromatic hydrocarbons (24 PAHs), 4 major elements, and 12 toxic trace metals (e.g., mercury and lead). The NS&T Program requires that each of its monitoring laboratories (1) use uniform sampling protocols to monitor coastal and estuarine environmental quality on a long-term national basis, (2) adhere to programmatic standards for accuracy and precision in analytical results, (3) analyze a set of calibration solutions and unknown chemical samples each year, and (4) participate in laboratory intercomparison exercises. For the NS&T's Specimen Banking, annually samples of sediment, fish livers, and shellfish tissue are collected from about ten percent of all NS&T monitoring sites, archived, and stored in liquid nitrogen freezers at about -150°C by the National Institute of Standards and Technology for future, retrospective analyses. NS&T Bioeffects Surveys, 2- to 4-year studies, are conducted on U.S. estuaries shown by NS&T monitoring results to have high levels of toxic chemicals. Recently, the NS&T Program began a sediment coring project to determine Historical Trends in such areas of concern as Long Island Sound, the Hudson-Raritan Estuary, Southern California Bight, and in Puget Sound. Similar studies are proposed for 1992 in Delaware Bay, Savannah Estuary, Chesapeake Bay, and San Francisco Bay. Information gathered through the NS&T Program can be applied to regional assessments to aid natural resource management. Coastal Contamination Assessments, prepared by NS&T staff, are reviews of the status of contamination and associated bioeffects integrated with data available from other sources on estuarine characterization, pollution sources, transport dynamics, etc.

a. Sediments

i. Spatial Trends of Contaminants in Sediments

The nationwide results from NOAA analyses of bottom sediments has been used to define the spatial distribution of contamination. It is important to know that contaminants are associated with particle surfaces, with sand-size particles having less contamination per unit weight of sediment than fine-sized silt or clay. To account for this, the NS&T sediment data has been adjusted to account for the sandy portion of sediment samples and to exclude very sandy samples (greater than 80 percent sand) in synthesis reports or assessments.

In Figure IV-22, concentrations for cadmium (Cd) and total PCBs (tPCB) are used as examples to show the distribution of trace metal and organic chemical concentrations in sediment. Generally, there are few high concentrations that stand out from the rest and these are usually from sites near densely-populated, urbanized centers of the country. In addition to the arithmetic distribution of these data, it is useful to examine the distributions of logarithms of the data in which the result approaches a log-normal, or bell-curve, distribution.

With log-normal distributions, a useful definition of "high" concentrations is "that where values are more than the mean plus one standard deviation." In practice, because we are dealing with normal distributions, about 17 percent of all the concentrations for each chemical will fall into the high category. For cadmium and tPCB, for example, the high concentrations correspond to 1.3 micrograms/gram (dry weight) and 200 nanograms/gram, respectively, as shown in Figure IV-22. High concentrations for other chemicals sampled in the NS&T Program are shown in Table IV-2.

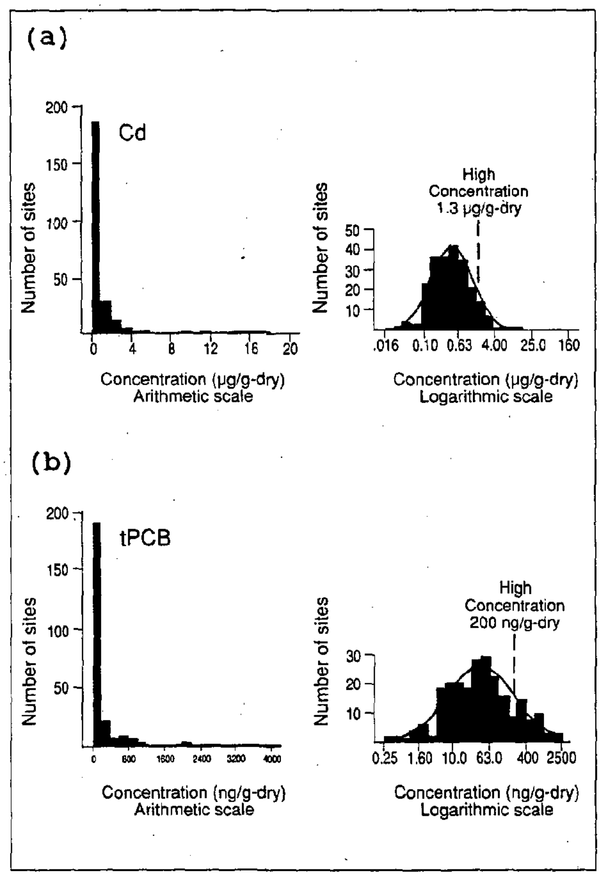


Figure IV-22 (a)-(b). Distributions of (a) cadmium (Cd) and (b) tPCB concentrations in sediment on arithmetic and logarithmic scales from NS&T Benthic Surveillance sites, 1984-86. (Courtesy Thomas P. O'Connor, Office of Ocean Resources Conservation and Assessment, NOAA National Ocean Service)

Table IV-2. Concentrations in sediment that are defined as "high" for NS&T sites. Concentrations are in units of micrograms/gram (dry) for trace metals and nanograms/gram (dry) for groups of organic compounds. (Courtesy Thomas P. O'Connor, Office of Ocean Resources Conservation and Assessment, NOAA National Ocean Service)

Trace Metals/Organic Compounds -- High Concentrations

Cd	Cr	Cu	Pb	Hg	Ag	Zn	tDDT	tCdane	tPCB	tPAH
1.3	230	87	87	0.51	1.2	280	40	5.5	200	3900

On a national scale, particularly for sites with three or more high concentrations of contaminants, it was found that high contaminant contaminations were associated with urbanized areas of the northeast states and those near San Diego, Los Angeles, and Seattle on the west coast. The association of higher levels of sediment contamination with populated areas is not a surprising result. High chemical concentrations are most often found near discharges and centers of industrial activity. Sampling on a much finer spatial scale than the NS&T Program would probably reveal higher absolute contaminant concentrations. This fact illustrates the need for more detailed monitoring programs in selected areas for local decision-making.

ii. Temporal Trends of Contaminants in Sediments

Near-surface (surficial) measurements of the top 1-3 cm of sediment can be used to describe the spatial distribution of contamination but the periodic analyses of surficial sediments requires a knowledge of rates of particle deposition and rates of sediment mixing. With only five years of measurements, the NS&T Program is relying instead on determining chemical trends back to pre-industrial times through its sediment coring project. Started in 1990, valid trends should be available soon from the results of coring studies in selected study areas.

b. Bivalve Mollusks

Since 1986, the NS&T Mussel Watch Project has been monitoring the concentrations of 70^{+} chemicals in bivalve molluscan tissues at more than 240 sites. Nationwide, data are collected for several mussels, *Mytilus* species and *Mytilus californianus*, two oysters, *Crassostrea virginica* and *Ostrea sandvicencis*, and the smooth-edge jewelbox, *Chama sinuosa*. The central reason for analyzing mollusks is to establish temporal trends in contamination. Mussels and oysters can change their contaminant levels over short periods of time in response to changes in their surroundings. This and the fact they are basically immobile makes them ideal for monitoring changes in chemical concentrations in the coastal environment.

Decadal trends in trace-metal contamination have been sought by comparing NS&T data of 1986 through 1988 with data from analyses of mussels and oysters collected in 1976 through 1978 by a previous "mussel watch" program sponsored by the U.S. Environmental Protection Agency. Statistically, since the earlier program collected a single sample each year, it was necessary to aggregate three years of data for each decade. With the aggregated data it was possible to estimate differences in trace metal concentrations in mollusks at the 50 sites that were common to both programs. Comparison of the data between the sites demonstrates a decadal decrease in lead at 39 out of 50 sites. That decreases is statistically sufficient to infer a national decrease in lead concentrations since the late 1970s, a result consistent with the phase-out of leaded gasoline.

For copper, cadmium, silver, and zinc the directions of change were not significant in either a positive or negative direction. However, for cadmium, there were 12 sites where the 1970s data were statistically different from the NS&T data, and 11 of those cases the 1970s concentrations were higher. Conversely, for 18 of the 22 sites where copper concentrations were statistically different they were lower in the 1970s. This increase in copper may reflect the fact that of all the metals measured in both programs, copper is the only one whose annual use in the United States has shown an increase since the mid-1970s. Large decreases in concentrations of synthetic chlorinated hydrocarbons in mollusks and other organisms occurred in the 1970s and continue now, but at a less dramatic rate.

c. Fish

i. Biological Effects of Contaminants

Since 1984, NOAA's National Marine Fisheries Service (NMFS) laboratories, in cooperative agreement with NOAA's National Ocean Service, have been monitoring, through the NS&T Benthic Surveillance Project, the biological effects of contaminants in fish , and concurrently measuring 70^+ chemical contaminants in fish livers, fish stomach contents, and associated surficial sediments. An extensive data base has evolved over the past eight years on Benthic Surveillance observations on nationwide incidences of such histopathological diseases as liver lesions (cancerous neoplasms) and fin rot, aryl hydrocarbon hydroxylase responses, and genetic damage (DNA-adducts) in fish exposed to contaminants. Since 1986, the NS&T Program also has conducted intensive, 2- to 4-year studies on the effects of chemical contaminants in selected areas of concern. Bioeffects surveys have been conducted or are underway in Boston Harbor, Long Island Sound, Hudson-Raritan Estuary, Tampa Bay, Southern California Bight, and San Francisco Bay. The Environmental Conservation Division of the NOAA Northwest Fisheries Science Center in Seattle, the NMFS Beaufort Laboratory, Woods Hole Oceanographic Institution, and others are conducting bioeffects studies on such topics as reproductive impairment, disease incidences, genetic damage, elevated biochemical response systems, and toxic responses to sediment and water samples. Results are linking bioeffects observations to high concentrations of selected chemical contaminants.

ii. Reproductive Impairment

Additional to NS&T monitoring and bioeffects surveys, closely related biological effects research, partly funded by NOAA's Coastal Ocean Program, is being conducted by the Environmental Conservation Division of the NOAA Northwest Fisheries Science Center in Seattle, WA. Over the years, this same laboratory has conducted numerous studies on the effects of chemical contaminant exposure on reproductive processes in bottom-dwelling fish. English sole was chosen as the target species for this research because previous studies had indicated that English sole is particularly sensitive to contaminants, and it is a species indigenous throughout much of the study site, Puget Sound. Early studies had shown that in gravid fish exposed to aromatic hydrocarbons, such as benzo(a)pyrene, these compounds and their biotransformation products were deposited in their gonads. Additionally, analyses of ovarian macromolecules showed binding of benzo(a)pyrene metabolites, indicating the presence of reactive and potentially toxic metabolites in the gonads.

Subsequent studies have shown reduced reproductive success in English sole living in contaminated urban areas, such as Eagle Harbor and the Duwamish Waterway in Puget Sound. Among the effects observed in females were: inhibition of oocyte development, inhibition of spawning, depressed plasma estradiol levels, and reduced egg weight. In female fish brought from contaminated areas and induced to spawn in the laboratory with hormone injections, spawning was roughly one-third as successful as it was in fish collected from an uncontaminated reference site. Also, when the fish did spawn, the viability of their offspring was reduced compared to that for fish from less contaminated sites. However, when fertilization success and larval viability were assessed in running ripe fish sampled near urban spawning grounds, it was found that the levels of contaminants were low in all animals sampled, and that no statistically significant relationship could be found between contaminant levels in tissues and larval viability or fertilization success. The relatively low levels of contaminants in running ripe fish from spawning grounds, in combination with evidence of inhibited ovarian development and spawning in fish from polluted sites, suggests that fish from sites with relatively high levels of contaminants may not be entering the spawning population.

In addition, in these studies the reproductive abnormalities were statistically linked to alterations in chemical and biochemical parameters (bioindicators) indicative of contaminant exposure. Using multivariate statistical techniques, several bioindicators were found to be associated with impaired ovarian maturation. The bioindicators studied were: hepatic aryl hydrocarbon hydroxylase activity (an enzyme involved in the metabolism of xenobiotics), tissue (liver and ovary) concentrations of PCBs, fluorescent aromatic compounds in bile (e.g., metabolic products of aromatic hydrocarbons). This statistical treatment also included other factors such as fish size or age which could be separated from effects of the contaminants (Figure IV-23). A correlation was observed between aromatic hydrocarbon contamination and impaired ovarian development, whereas decreased fertilization success, low egg weight, and impaired larval viability were correlated with exposure to PCBs.

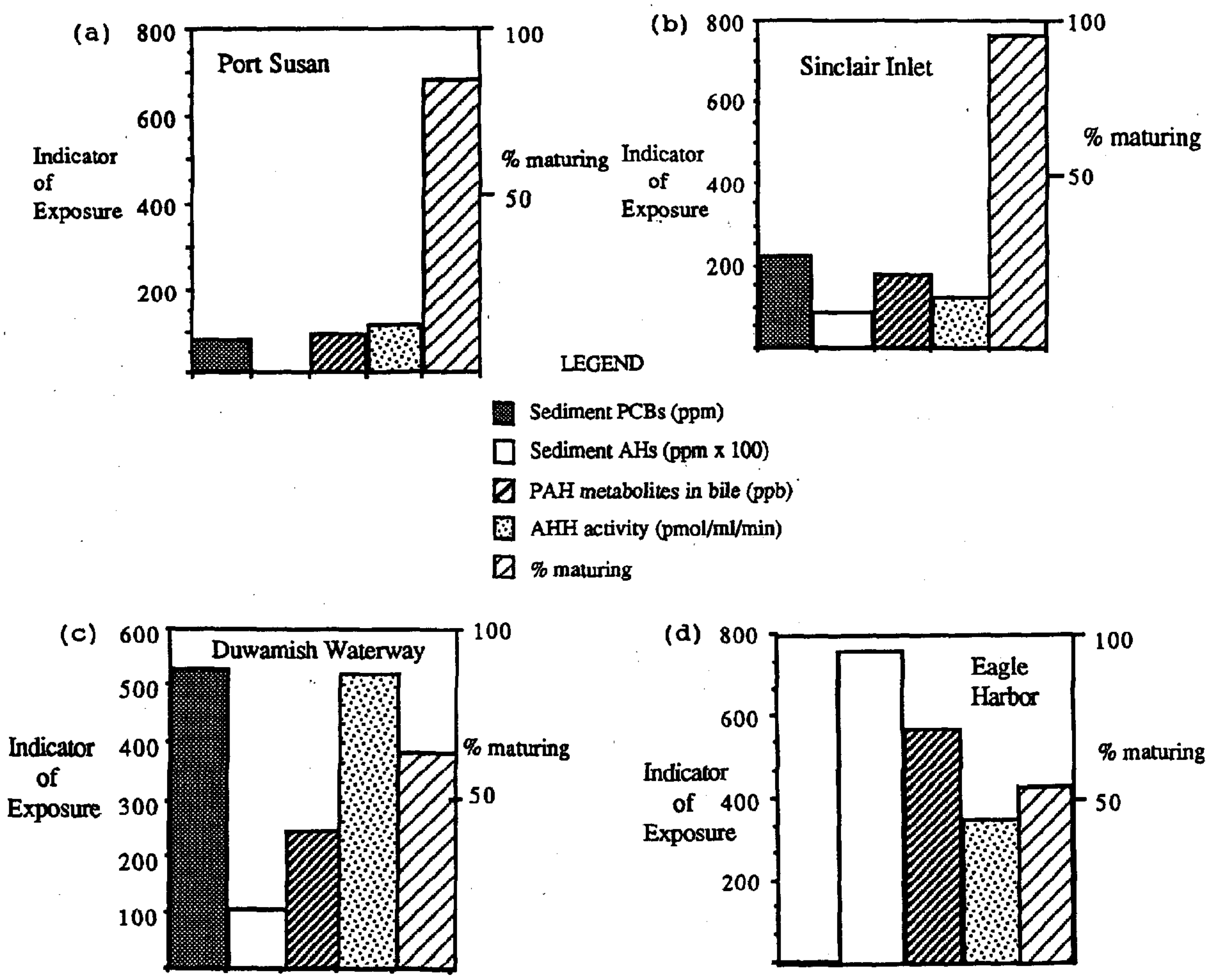


Figure IV-23 (a)-(d). Indicators of contaminant exposure and proportion of female English sole undergoing ovarian maturation at four sites in Puget Sound: (a) Port Susan; (b) Sinclair Inlet; (c) Duwamish Waterway; (d) Eagle Harbor. Proportions of maturing females from Port Susan and Sinclair Inlet were significantly higher than those in females from the more contaminated sites. (Courtesy Usha Varanasi, Northwest Fisheries Science Center, NOAA National Marine Fisheries Service)

Further support of a link between contaminant exposure and reproductive impairment in populations of English sole was provided by additional laboratory studies. For example, injection of gravid female fish with contaminants extracted from Duwamish Waterway sediment showed a decline in circulating plasma estradiol levels similar to that observed in the field-sampled fish from contaminated sites. Current research includes studies to identify metabolic or physiological steps in the reproductive cycle of English sole which are disrupted by exposure of fish to toxicants, such as the effects of xenobiotic compounds on the activities of steroid metabolizing enzymes and on ovarian estradiol production.

iii. Liver Lesions

Field studies, partly supported by the NS&T Benthic Surveillance Project, conducted by Northwest Fisheries Science Center scientists in numerous sites in Puget Sound have indicated correlations between exposure to certain chemical contaminants and the presence of liver neoplasms in English sole. This research also characterized a variety of other liver lesions that: (a) commonly co-occur with neoplasms, (b) are involved in the initial steps in the histogenesis of liver neoplasms, (c) occur prior to the development of neoplasms, and (d) are generally found in wild fish at higher prevalences than neoplasms. These early lesions have been induced in the laboratory by exposing English sole to certain contaminants, such as benzo(a)pyrene and organic-solvent extracts from urban sediments, and are correlated with liver dysfunction as measured by certain serum chemistry parameters.

The thrust of this group's more recent work has been directed at assessing the utility of earlier-occurring lesions as reliable indicators of contaminant exposure in the marine environment. The main advantage of using liver lesions as bioindicators is that, when combined with supportive data on exposure and uptake of xenobiotic chemicals, they provide a fairly direct index for assessing sublethal effects of contaminants in wild fish. In particular, early liver lesions are especially valuable in biomonitoring programs where target fish species are often juveniles or subadults because liver lesions are rarely detected in young wild fish. These lesions should also provide useful indices of effects at sites exhibiting low-to-moderate levels of contamination, since liver neoplasms are primarily found in fish from highly contaminated sites.

Because these lesions occur prior to the appearance of neoplasms, they may provide an earlier as well as a more sensitive, histopathologic response to contaminant exposure in wild fish, thus increasing our ability to predict rather than document the deleterious biological effects of pollution (Figure IV-24).

To test the utility of early lesions as bioindicators, juvenile and subadult English sole and starry flounder captured from several sites in Puget Sound with varying degrees of contamination have been examined (Figure IV-25). As expected, neoplasms were detected at very low prevalences in these young fish from all sites, whereas higher prevalences of earlier-occurring lesions, such as preneoplastic lesions and regenerative lesions, were found in English sole and rock sole, and much higher prevalences of several types of earlier-occurring degenerative lesions (i.e., nuclear pleomorphism/megalocytic hepatosis and/or hydropic vacuolation of parenchymal cells) were detected in individuals of all three species, primarily from contaminated sites.

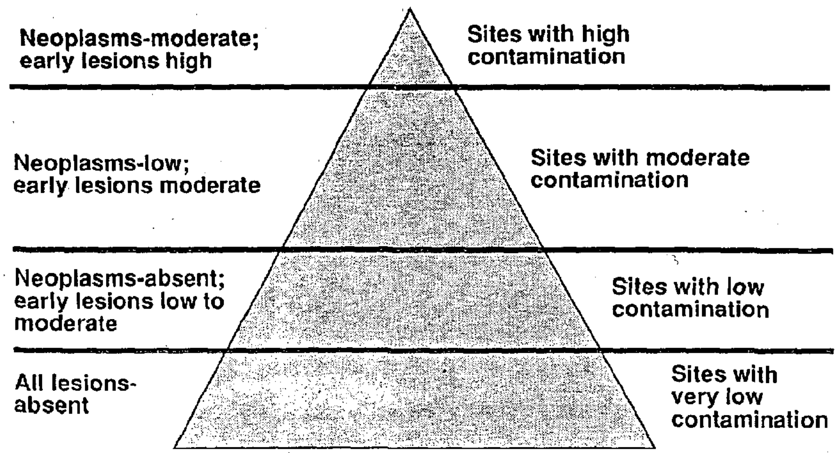


Figure IV-24. A model using prevalences of various contaminant-induced liver lesions in benthic fish from field survey data. (Courtesy Usha Varanasi, Northwest Fisheries Science Center, NOAA National Marine Fisheries Service)

All of these liver lesion types have been experimentally induced in fish in the laboratory by exposure to various toxicants, or have been shown to be statistically associated with contaminant exposure and the process of liver neoplasia in wild adult fish. Prevalences of these earlier-occurring lesions were significantly higher in subadult fish at the more contaminated sites as compared with the less contaminated sites in the above study. Moreover, prevalences of most lesion types in all three species could be significantly correlated with mean bile fluorescent aromatic compound levels, an indicator of recent exposure to aromatic hydrocarbons. In addition, prevalences of these earlier-occurring liver lesions as well as neoplasms have been recently shown to be significantly elevated in other species captured at other contaminated sites sampled within NOAA's National Benthic Surveillance Project (Figure IV-26) and are statistically correlated with results in previous studies on adult fish. These findings support the value of using certain liver lesions in addition to neoplasms as indicators of biological damage in juvenile or adult fish exposed to contaminants.

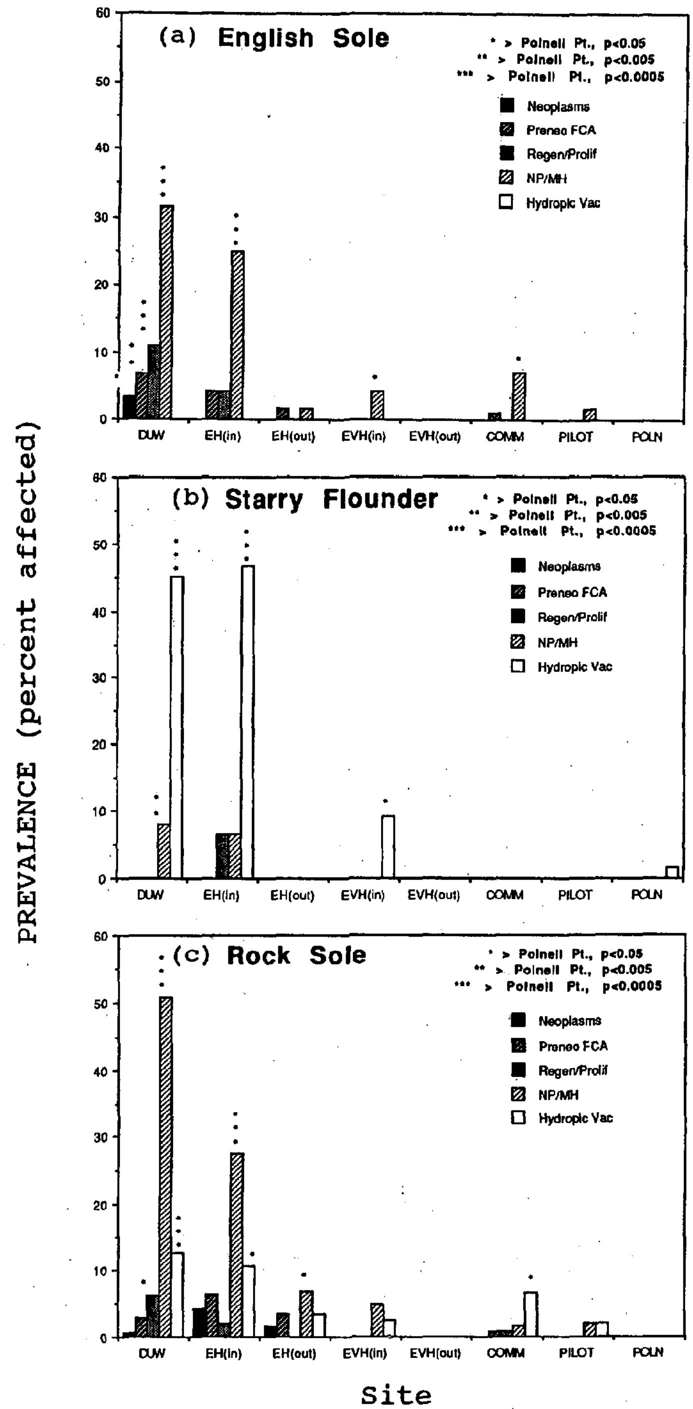


Figure IV-25 (a)-(c). Hepatic lesion prevalences in subadult (a) English sole, (b) starry flounder, and (c) rock sole from sites in Puget Sound. Keys in Table IV-3. (Courtesy Usha Varanasi, Northwest Fisheries Science Center, NOAA National Marine Fisheries Service)

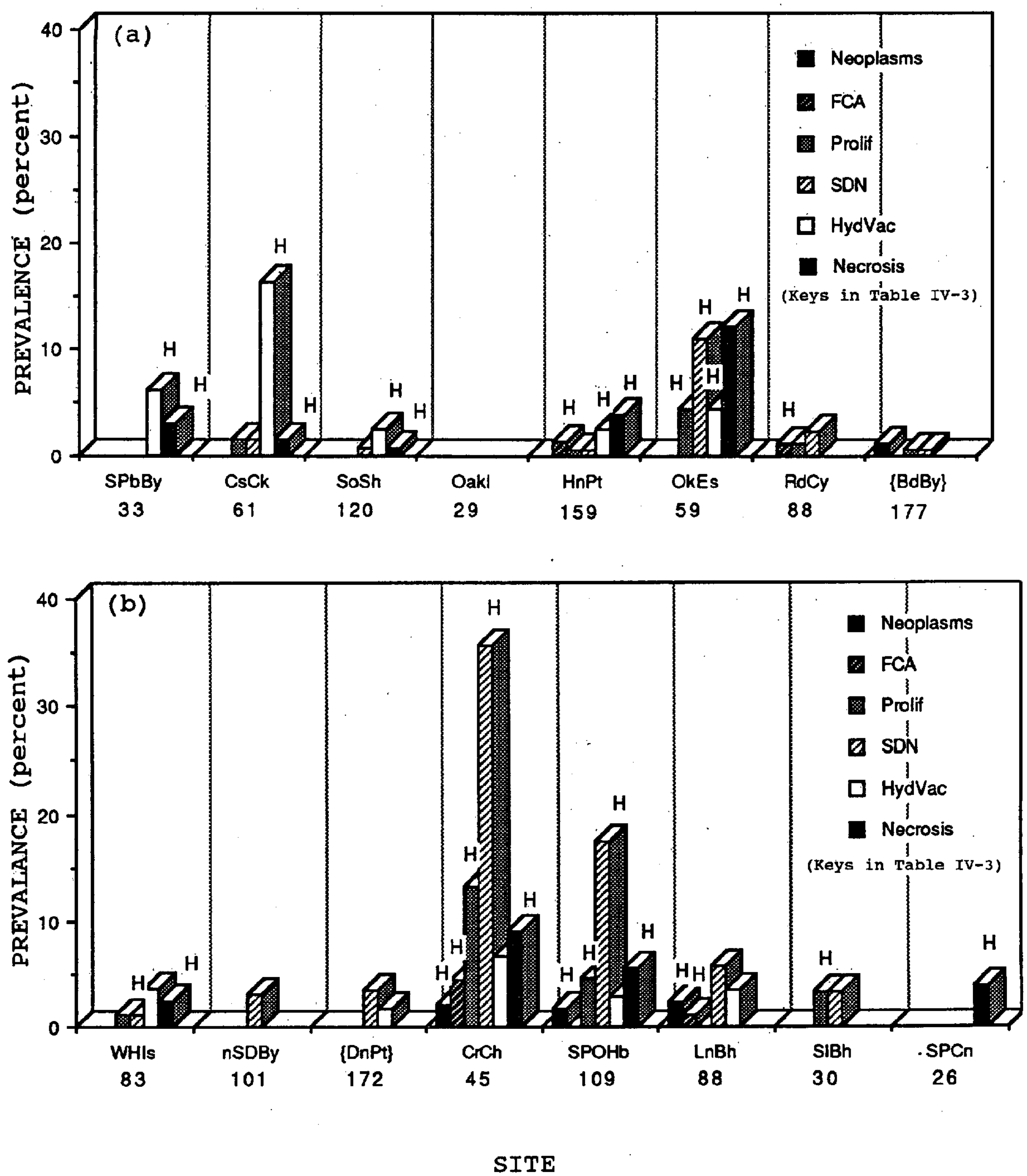


Figure IV-26 (a)-(b). White croaker liver lesions, (a) northern sites and (b) southern sites, National Benthic Surveillance Project, 1984-1988. (Courtesy Usha Varanasi, Northwest Fisheries Science Center, NOAA National Ocean Service)

Table IV-3. Keys to Figures IV-25 and IV-26. (Courtesy Usha Varanasi, Northwest Fisheries Science Center, NOAA National Marine Fisheries Service)

Figure IV-25

Sites:

DUW	Duwamish River
EH(in)	inside Eagle Harbor
EH(out)	outside Eagle Harbor
EVH(in)	inside Everett Harbor
EVH(out)	outside Everett Harbor
COMM	Commencement Bay
PILOT	Pilot Point
POLN	Polnell Point (reference site)

Lesion Category Abbreviations:

Preneo FCA	putatively preneoplastic foci of cellular alteration
Regen/Prolif	hepatocellular regeneration/biliary cell proliferation
NP/MH	hepatocellular nuclear pleomorphism/ megalocytic hepatosis
Hydropic Vac	hydropic vacuolation of hepatocytes, biliary epithelial cells

Figure IV-26

Sites: Northern

SPbBy	San Pablo Bay (San Francisco Bay)
CsCk	Castro Creek (San Francisco Bay)
SoSh	Southampton Shoal (San Francisco Bay)
Oakl	Oakland (San Francisco Bay)
HnPt	Hunters Point (San Francisco Bay)
OkEs	Oakland Estuary (San Francisco Bay)
RdCy	Redwood City (San Francisco Bay)
BdBy	Bodega Bay (reference site for northern stations)

Sites: Southern

CrCh	Cerritos Channel (San Pedro Bay)
SPOHb	San Pedro Outer Harbor (San Pedro Bay)
SPCn	San Pedro Canyon
LnBh	Long Beach
SlBh	Seal Beach
WHIs	West Harbor Island (San Diego Bay)
nSDBy	North San Diego Bay (San Diego Bay)
DnPt	Dana Point (reference site for southern stations)

Lesion Category Abbreviations:

FCA	putatively preneoplastic foci of cellular alteration
Prolif	nonneoplastic proliferative lesions (e.g., hepatocellular regeneration, biliary hyperplasia)
SDN	specific degeneration/necrosis (e.g. nuclear pleomorphism, megalocytic hepatosis)
HydVac	hydropic vacuolation of hepatocytes, biliary epithelial cells
Necrosis	nonspecific degeneration/necrosis (e.g. hepatocellular coagulative necrosis)

d. Invertebrates

Although there has been a concerted effort to understand and monitor the effects of contaminants on different species of fish, less is known about the effects of contaminants invertebrate species. Yet invertebrates represent approximately 97 percent of all species in the animal kingdom and may also be at risk for exposure to environmental contaminants. Invertebrate species are also vulnerable because many do not appear to have the systems for detoxifying and removing xenobiotics that vertebrates have.

Currently NOAA's National Status and Trends Program (NS&T) includes some biological measurements for invertebrate species in its nationwide yearly environmental monitoring efforts, however, the primary focus is on mollusks. Because invertebrates span a large number of phyla, they exhibit a wide variety of physiological strategies for dealing with xenobiotics. For example, the ability to metabolize aromatic hydrocarbons is virtually absent in the more primitive phyla, such as the cnidarians (e.g., jellyfish) and porifera (i.e., sponges), and is only questionably present in the molluscan phylum. Whereas in the more evolutionary advanced invertebrate phyla, such as the echinoderms (e.g., starfish, sea urchins), arthropods (e.g., crustaceans), and annelids (e.g., polychaete worms) this ability generally exists. Thus it is reasonable that any large-scale assessment of coastal degradation should incorporate a range of invertebrate species, including those that accumulate contaminants and those that metabolize them. This is beginning to happen in the case of NOAA's Coastal Ocean Bioeffects Surveys. Intensive monitoring of several highly contaminated sites, such as Raritan Bay in New Jersey, now includes several sediment bioassays (as a measure of invertebrate health) in the suite of measurements performed.

Scientists from the Northwest Fisheries Science Center's Environmental Conservation Division in Seattle are now assessing the possible adverse health effects of sediment-associated contaminants on a number of sediment-dwelling invertebrate species. Sediment samples which are routinely collected and chemically analyzed as part of NOAA's National Benthic Surveillance Project are now being further studied for their possible biological impact by using a suite of newly developed sublethal sediment bioassays rather than the traditional mortality-based assay.

Particular interest has focused on sublethal assays because they may prove especially useful in testing the majority of coastal environments exhibiting low-to-moderate levels of contamination, and for assessing long-term or chronic effects of contaminant exposure. Such information can be used to indicate early on the to protect these habitats. Laboratory studies using natural or artificially amended sediments are also used linking various concentrations of sediment-associated contaminants to their possible effects on invertebrate organisms.

Two such newly sublethal bioassays, one using a sediment-burrowing polychaete worm and the other using juvenile sand dollars, were successfully used to evaluate toxicity of sediments collected from Puget Sound as well as from 18 sites sampled along the west coast as part of the NS&T Program. Acute mortality rarely occurred with these sediments, but growth was found to be significantly depressed in invertebrates exposed to many of the urban sediment samples. Growth of the worms and sand dollars was affected when exposed to sediments from the following contaminated sites: North and South San Diego Bay; east San Pedro Bay and Cerritos Channel near Los Angeles; Hunter's Point and Oakland Estuary in San Francisco Bay; and Elliott and Commencement Bays in Puget Sound (Figures IV-27).

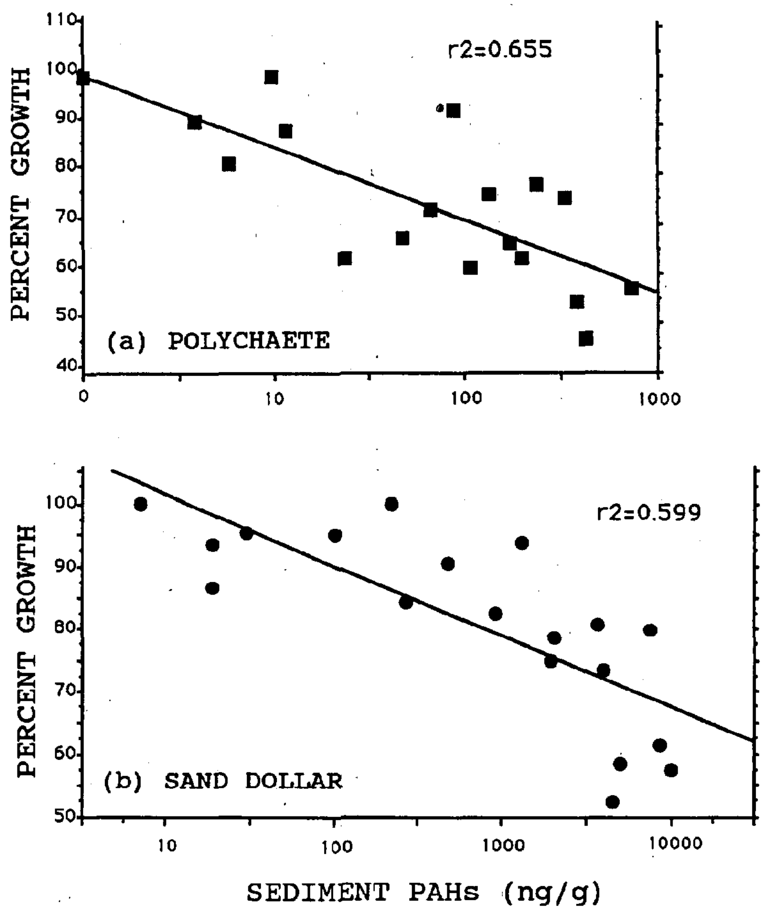


Figure IV-27 (a)-(b). Effect of sediment contaminant levels on (a) polychaete and (b) sand dollar growth at 18 different sites in NOAA's National Benthic Surveillance Project, 1989. Concentrations of polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in nanograms per gram (ng/g). (Courtesy Usha Varanasi, Northwest Fisheries Science Center, NOAA National Marine Fisheries Service)

Invertebrate growth, as measured by a change in wet weight, was reduced by nearly 50 percent following exposure to some of these contaminated sediments as compared to the reference sediment. The sediment chemistry data showed a high correlation between concentrations of selected contaminants (e.g., aromatic hydrocarbons, PCBs) and reduced growth of polychaetes and sand dollars. Furthermore, animals exposed to urban sediment samples had significantly lower deoxyribonucleic (DNA) and protein content than animals exposed to the reference sediments. Invertebrate growth following exposure to sediments from nonurban sites was not significantly different from growth of these organisms on the reference sediment.

Thus, these studies highlight that if mortality alone had been used as a measurement of invertebrate health, most of the sediments would have yielded negative test results. However, when a more subtle indicator of invertebrate health was used, such as growth, just the opposite was found: now most of the test sites revealed definite signs of impaired invertebrate health in those species tested.

These results suggest that measurements of impaired growth in some invertebrates will provide a far more sensitive measurement of sediment toxicity than acute mortality alone, particularly in those sites exhibiting low to moderate levels of contamination. New research on the polychaete bioassay is now underway to examine that possible impact of contaminants on this organism's reproductive success as another sublethal indicator of sediment toxicity.

e. Marine Mammals

Marine mammals are important for studying aquatic contamination. They are at the top of the marine food chain and by studying them it may be possible to learn how chemical contaminants are transported up the food chain. Recent strandings of gray and pilot whales and other marine mammal species have created understandable public concern. The reasons behind such beachings are generally unknown, but have sometimes been attributed to toxic contaminants. The lack of concrete information on tissue levels of contaminants often leads to speculation.

i. Marine Mammal Tissue Bank

An important component of studying chemical contaminants in marine mammals is the newly created NMFS Marine Mammal Tissue Bank (MMTB) program under NMFS's Office of Protected Resources. The primary objective of this program is to create a databank of tissue samples to which scientists can return in the future as new and improved information and techniques become available should future research link a new chemical with marine mammal deaths. In such a case, scientists would be able to go back to the earlier, preserved samples to check if that same chemical was present at the time but either was not looked for or was not capable of being detected using the current methods. Developing a good baseline of tissue samples requires a major effort to get the most out of the few samples that become available via strandings, incidental or accidental deaths, subsistence hunting, and kill permits. These samples will be frozen and saved indefinitely.

Scientists within the Environmental Conservation Division of the Northwest Fisheries Science Center, in cooperation with the MMTB, have recently begun analyzing tissues from stranded marine mammals to document levels of chemical contaminants such as PCBs, DDTs, and metals using state-of-the-art methodologies. Because of the very high lipid content in most marine mammal tissues, standard tissue clean-up methods had to be significantly modified to reduce interference from the lipid in the sample extracts to permit chemical analyses. Moreover, biochemical studies are being conducted on marine mammal tissue samples to assess exposure of the animals to certain chemical contaminants, particularly to aromatic hydrocarbons. Among the marine mammals investigated to date are: bottlenose dolphins, fur seals, gray whales, harbor porpoises, harbor seals, pilot whales, and Steller sea lions (Figure IV-28).

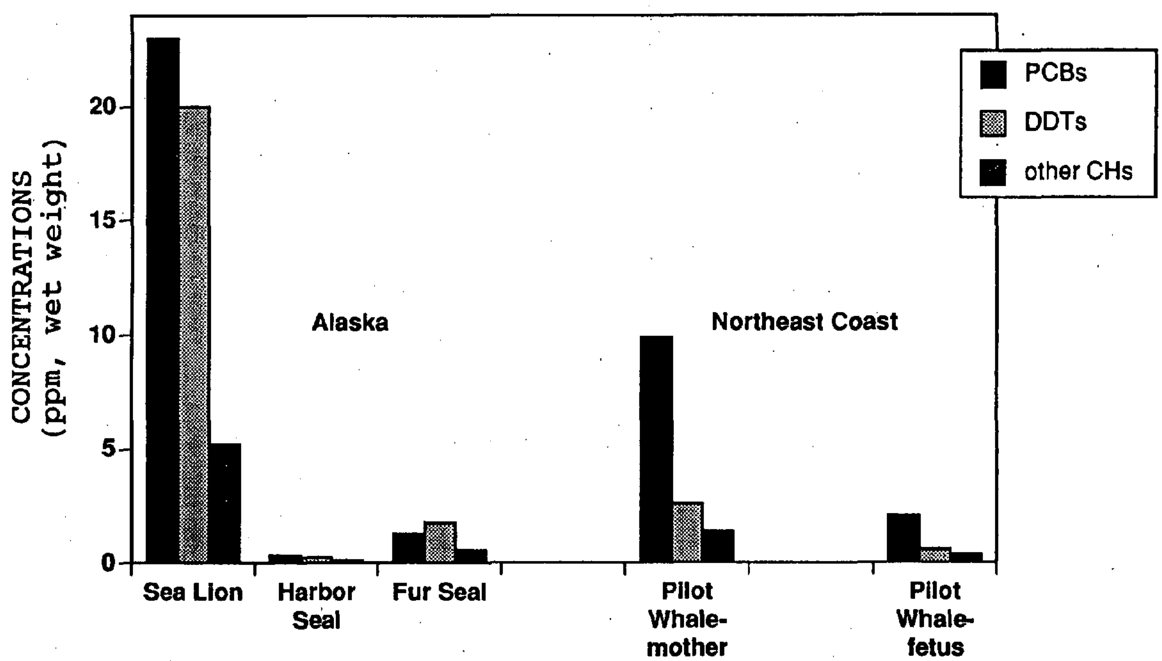


Figure IV-28. Concentrations of chlorinated hydrocarbons in blubber of marine mammals. Concentrations of PCBs, DDTs, and other chlorinated hydrocarbons (CHs) in parts per million (ppm), wet weight. (Courtesy Usha Varanasi, Northwest Fisheries Science Center, NOAA National Marine Fisheries Service)

ii. Marine Mammal Quality Assurance

Data of the highest quality is essential in this program. Thus NOAA has adopted a quality assurance program with two main components. One component of the program will be further standardization of methods in conjunction with the organic analytical research division of the National Institute of Standards and Technology (NIST). For example, instrument parameters and column clean-up methods can be modified to insure optimum results while working with the lipid-rich marine mammal tissues, especially blubber. A second phase will include the analyses of a whale blubber homogenate standard reference material prepared by NIST and a cod liver oil standard reference material.

PROTECTED RESOURCES

Our fish, wildlife, and natural habitats are valuable economic, aesthetic, and recreational assets and, as such, are protected from exploitation. Numerous legislative actions conserve and protect these resources. Many of these laws have designated the Secretary of Commerce (through the National Oceanic and Atmospheric Administration) as the federal authority responsible for their implementation. Significant among the laws that give NOAA primary responsibility to protect marine species and critical habitats are the Endangered Species Act, Marine Mammal Protection Act, Magnuson Fishery Conservation Act, and the Marine Protection, Research, and Sanctuaries Act. In addition, NOAA provides recommendations to other agencies concerning federal activities that effect marine, estuarine, and anadromous species and critical habitats through such legislation as the Clean Water Act and the National Environmental Policy Act.

a. Sea Turtles

Marine turtles are highly migratory species found in all oceans of the world. The six species found in the Atlantic Ocean include the loggerhead, green, Kemp's ridley, leatherback, hawksbill, and olive ridley turtles. Of these six, all but the olive ridley are found in United States Atlantic waters. Within the Pacific, all six species are found. In Hawaiian waters, the green and hawksbill are the most abundant species. Off the United states west coast, the loggerhead, leatherback, and olive ridley turtles are the most commonly reported species.

Under a memorandum of understanding with the U.S. Fish and Wildlife Service (USFWS), NOAA's National Marine Fisheries Service (NMFS) has been given the authority to protect and conserve marine turtles. The USFWS maintains authority while turtles are on land. Under the Endangered Species Act of 1973, all marine turtles are listed as endangered or threatened. The Kemp's ridley, hawksbill, and leatherback turtles are listed as endangered throughout their ranges. The loggerhead and olive ridley turtles are listed as threatened throughout their U.S. ranges. In the United States, the green turtle is listed as threatened, except for the Florida nesting population which is listed as endangered (Table IV-4).

Table IV-4. Annual number of sea turtles nesting on U.S. beaches (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

	Historical Level	Current Level	Current Level	Status in U.S.
Atlantic				
Loggerhead	--	18,000-21,000	Stable	T[a]
Green	--	600-800	Increasing	T,E[b]
Kemp's ridley	40,000	700	Declining[c]	E
Leatherback	--	--	--	E
Hawksbill	--	--	Declining	E
Pacific				
Loggerhead	--	--	--	T
Green	10,000[d]	2,200[d]	Increasing[e]	T
Olive ridley	--	--	--	T
Leatherback	--	--	--	E
Hawksbill	--	75[f]	--	E

a. T=Threatened; E=Endangered.
b. Endangered in Florida; threatened elsewhere in the U.S. Atlantic.
c. Declining at average rate of 3 percent per year since 1978.
d. Historical level for Hawaii only; current level is 2000 in Hawaii and 100-300 in American Samoa; current levels in Guam unknown.
e. Trend in Hawaii only, monitored at French Frigate Shoals; however, great concern exists over increasing frequency of fibropapilloma disease in all Hawaiian green turtles.
f. Current abundance in Hawaii; current abundance in Guam and American Samoa is unknown.

i. Population Abundance

Historical information on the abundance of sea turtles in U.S. waters is limited. Given these limitations, it is difficult to assess the status of turtle stocks over the long term. The most available index to evaluate population status and trends is the estimated number of nests or nesting females over aggregate nesting sites. Loggerhead, green, and Kemp's ridley turtles nest on the Atlantic and Gulf coast. The 1982-84 number of loggerheads nesting females from North Carolina to Florida was 18,000-21,000. The majority of nesting occurs along the Florida east coast where the number of nests has been stable over the past 5 years.

The Kemp's ridley turtle is only known to nest in significant numbers at a single location on the Mexican Atlantic coast where the number of nests has been stable over the past 5 years. In 1947, 40,000 females were observed nesting on a single day in the nesting season. Now, about 700 females nest along this same beach throughout the whole season. This number has been stable or slightly increasing over the past 4 years. The documented decline in Kemp's ridley is probably indicative of declines experienced by other sea turtle species (Figure IV-29).

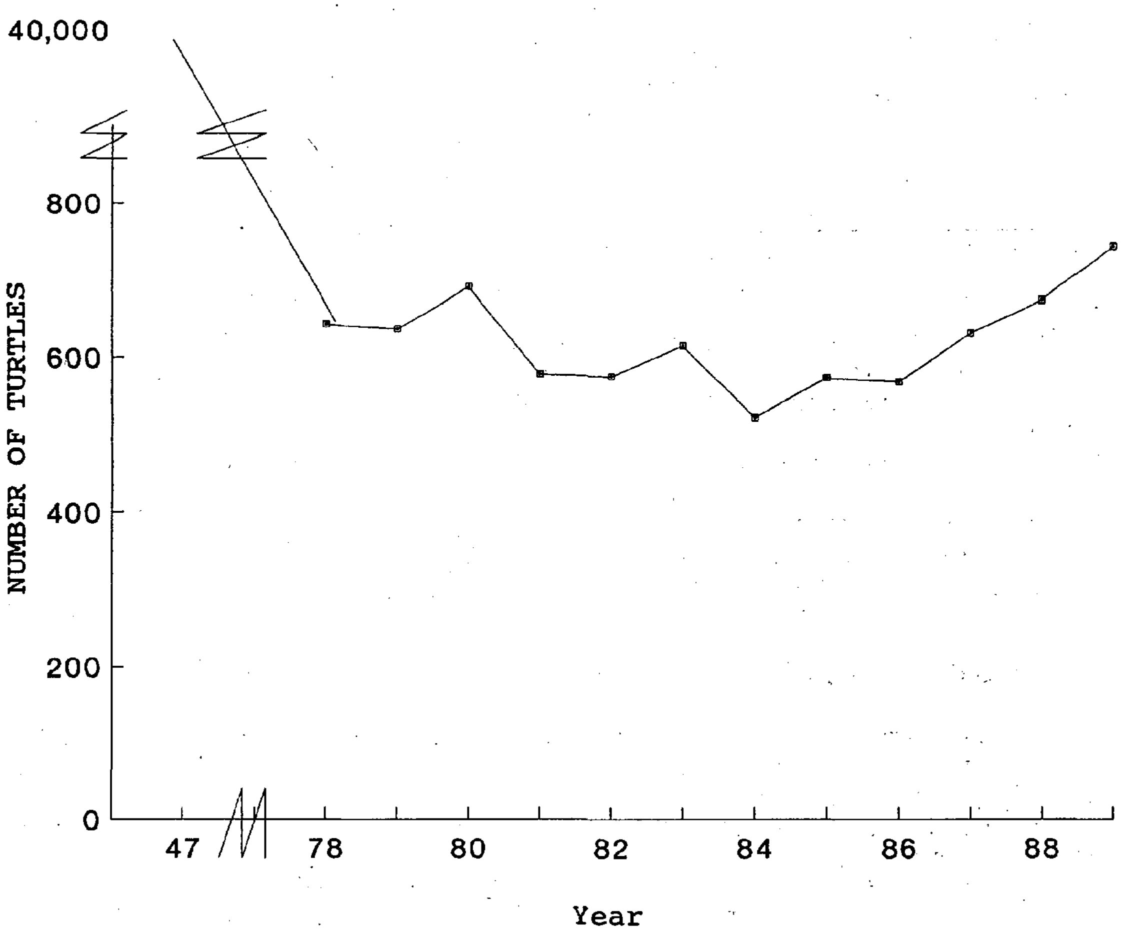


Figure IV-29. Annual number of Kemp's ridley sea turtles nesting on U.S. beaches. (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

Historically, the green sea turtle supported significant fisheries along the Florida and Texas coasts, although nesting of this species on U.S. beaches has always been limited. In the late 1800s, it was reported that 2,000 females nested at Key West, Florida. Currently the number of green turtles nesting along the Florida coast is probably no more than 600-800. However, it appears that the abundance of juvenile and sub-adult turtles in inshore waters of Florida has recently returned to historical levels. There are no historical estimates for the numbers of hawksbill or leatherback turtles nesting on U.S. Caribbean beaches. The hawksbill has been heavily exploited within its range and is likely to continue to decline. The status of the leatherback turtle is not known in U.S. waters. In the Pacific, extensive studies of the Hawaiian green turtle population are being conducted on nesting beaches and inshore habitats. Since 1973, surveys of nesting females have been conducted annually at French Frigate Shoals in the northwestern Hawaiian Islands by NMFS and the USFWS. These surveys indicate that the adult green turtle population may currently number about 2,000 and that it is gradually increasing. No accurate historical record of green turtle population sizes exists. Despite an apparent increase in the nesting population, there is growing concern that fibropapilloma disease, which has infected green turtles of all ages in many inshore feeding and resting areas, may significantly impede population recovery.

The Hawaiian hawksbill turtle population is very small with only 12-15 nests recorded each year. Little is known of the biology of this species in Hawaii or of trends in the population size. In the north Pacific there are concerns about mortality to marine turtles in the pelagic environment due to high-seas driftnets. Turtle bycatch rates are being monitored on driftnet vessels by U.S., Canadian, Japanese, Korean, and Taiwanese scientific observers. The extent to which the driftnet fisheries affect U.S. turtle populations is unknown.

While sea turtles are protected in U.S. waters, turtle habitat worldwide continues to be negatively impacted. Coastal development reduces the quality and quantity of available nesting habitat. Turtles are also impacted through entanglement in fishing gear, and they represent significant bycatch in various fisheries. Perhaps as many as 10,000 sea turtles are taken annually in shrimp trawl fisheries. The increasing presence of debris such as tar balls and plastics that are directly ingested negatively impacts turtles. The extent of these negative impacts are not limited to the United States, and there have been increased efforts to promote international cooperation in marine turtle recovery.

ii. Marine Turtle Fibropapilloma

Green turtles develop lobulated tumors (fibropapilloma) on their skin, scales, scutes, eyes and surrounding tissues, oral cavities, and viscera. The cause of this disease is unknown but during the last 10 years the scope and magnitude of fibropapilloma in green turtles has grown to epidemic proportions almost simultaneously at several marine habitats in Florida, the Hawaiian Islands, and a few other locations (Figure IV-30). The disease represents a significant threat to the survival of this protected marine turtle.

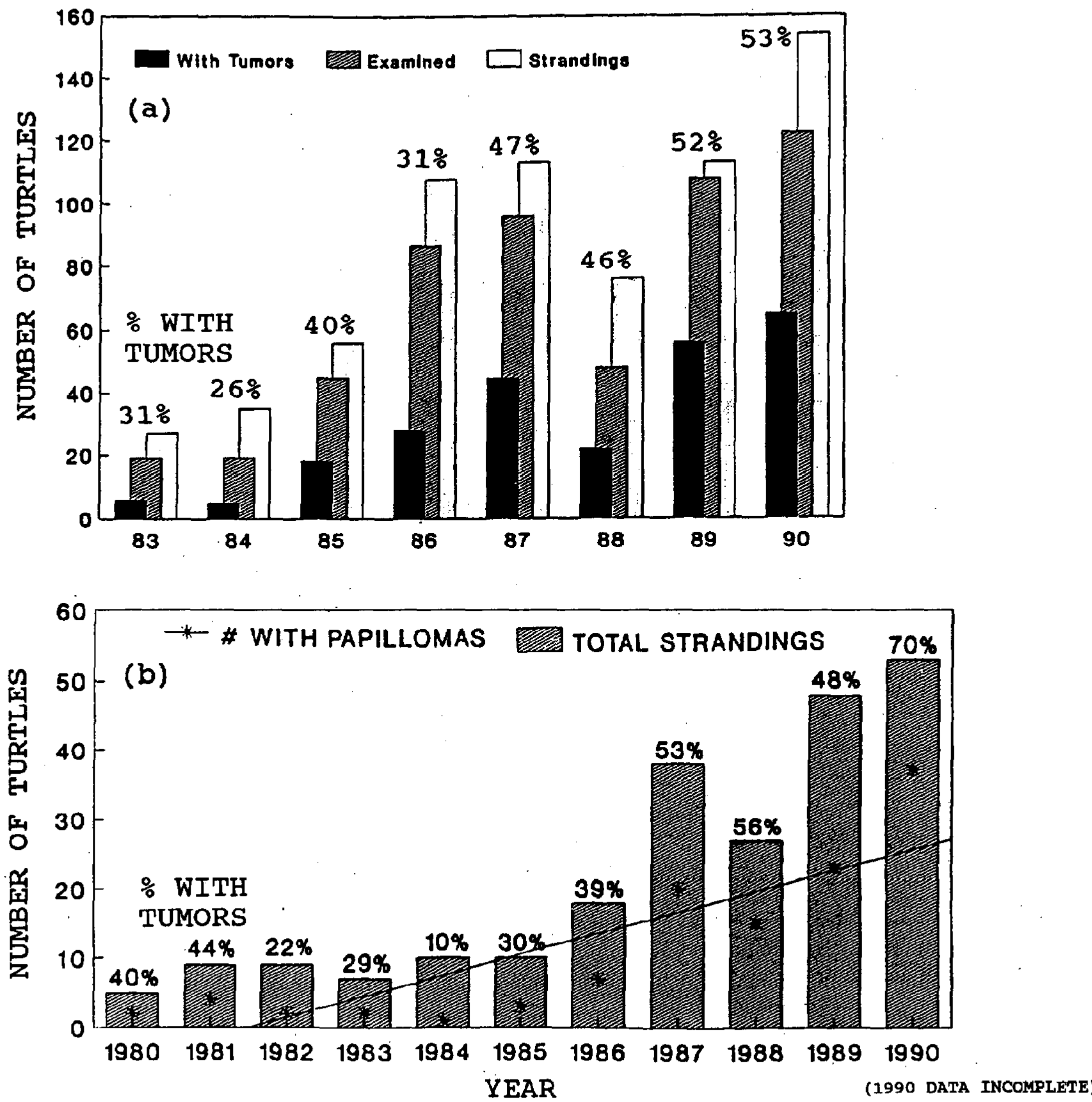


Figure IV-30 (a)-(b). Green turtle strandings and percentage with fibropapilloma in (a) Hawaii, 1983-1990, and (b) the Florida Keys, 1980-1990. Florida strandings reported through the Sea Turtle Stranding and Salvage Network. (Courtesy George H. Balazs, Honolulu Laboratory, Southwest Fisheries Science Center, and Wendy Teas, Miami Laboratory, Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

The cause of fibropapilloma remains unknown. The impact of the disease on the afflicted populations can have, indeed may already have had, serious consequences. The nature of this disease and its cause must be determined in order to develop a long-term disease management program. To deal with this situation, NOAA's NMFS sponsored a workshop on marine turtle fibropapilloma in Honolulu, Hawaii, in December 1990. The objective of the workshop was to bring top scientists together to discuss what is known about marine turtle fibropapilloma and to devise a comprehensive and cooperative research plan on the cause of this disease. Results of the workshop were published in a technical memorandum by the NOAA's NMFS Honolulu Laboratory in March 1991 entitled "Research Plan For Marine Turtle Fibropapilloma" (NOAA-TM-NMFS-SWFSC-156).

b. Selected Marine Mammals

Thirty-six species of marine mammals range the U.S. Atlantic and Gulf of Mexico waters (34 whales, dolphins, and porpoises, and 2 seal species). Their status is poorly known, but some, like the right whale, mid-Atlantic coastal bottlenose dolphin, and harbor porpoise, are under stresses that may affect their survival.

Forty-two species of marine mammals occur in U.S. Pacific waters (31 whales, dolphins, and porpoises, and 11 species of seals and sea lions). Fourteen are commonly seen along the coast (gray whale, bottlenose dolphin, harbor seal, and others), whereas the 28 others frequent offshore or remote island waters (beaked whales, ribbon seal, Hawaiian monk seal, and others), or are severly reduced in numbbers and thus seldom seen (blue whale, right whale, Guadalupe fur seal, for example).

i. Atlantic Bottlenose Dolphin

Bottlenose dolphins range throughout the Gulf of Mexico and the U.S. Atlantic waters. Figure IV-31 illustrates their distribution and seasonal patterns along the Atlantic coast. There appear to be nearshore and offshore stocks along the U.S. Atlantic coast.

During the summer and fall of 1987 and winter of 1988 an apparent epidemic resulted in the death and stranding of an unusually large number of Atlantic bottlenose dolphins from New Jersey to central Florida. Population surveys and biological samples suggest that the mortality was principally from a mid-Atlantic coastal, migratory stock of dolphins. Available data suggest a decline of at least half of the stock may have occurred.

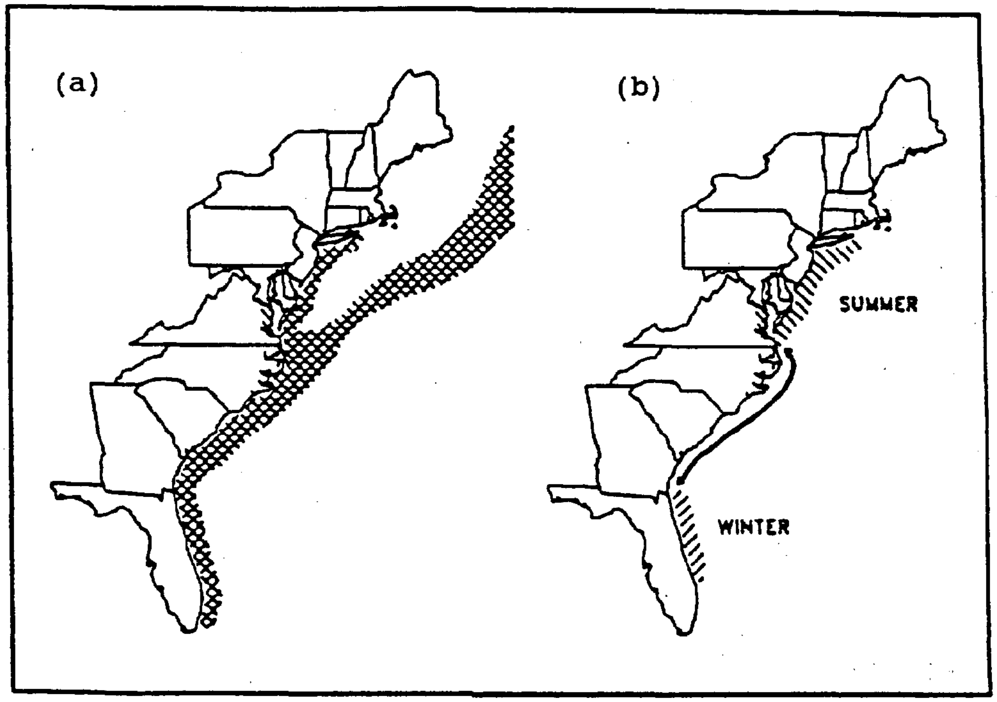


Figure IV-31 (a)-(b). (a) Distributional range of bottlenose dolphins along the U.S. Atlantic coast and (b) areas of major concentrations of coastal migratory stock of bottlenose dolphins during summer and winter. (Courtesy Southeast Fisheries Science Center, NOAA National Marine Fisheries Service)

At present, there is no comprehensive estimate of the size of the stock of bottlenose dolphins in U.S. waters. The number of dolphins comprising the numerous stocks throughout the U.S. Gulf and Atlantic waters prior to 1983 may have been at least 23,000 individuals. Historically, about 15,000 animals are thought to have lived in mid-Atlantic nearshore waters. The estimated average mid-Atlantic summer abundance of bottlenose dolphins is believed to have ranged from about 4,000 to 13,000 animals, including both nearshore and offshore groups, in 1979-1981.

ii. Eastern Tropical Pacific Dolphins

In 1990, the NOAA Southwest Fisheries Science Center completed the fifth of an annual series of large-scale Monitoring of Porpoise Stocks (MOPS) surveys in the eastern tropical Pacific (ETP). Management of the tuna-dolphin problem is currently based on detecting possible reductions in ETP dolphin population over time due to the tuna purse-seine fishery. For this purpose relative estimates of abundance with minimum variance is considered sufficient. However, if quotas based on incidental dolphin mortality are to be instituted on an international basis, there will be a need for absolute estimates of population size. New analysis procedures will ultimately lead to absolute estimates and, until that work is complete, the annual estimates for each stock of dolphins will be reported as a relative index.

Figure IV-32 shows estimates of relative abundance for nine stocks of four ETP dolphin species that are impacted by the tuna purse-seine fishery. The estimates of relative abundance shown in Figure IV-32 are highly variable, and it is difficult to discern a pattern. No overall trend was detected during the 5-year study period, which might have been expected if mortality due to the tuna purse-seine fishery in the ETP were having an impact on the populations. However, the data do not warrant a conclusion that no impact is occurring. The statistical power of detecting even a large decline during a 5-year period given the observed variability of the estimates is low.

iii. Bowhead Whale

The endangered bowhead whale has ranged as far as the polar ice fields of the Northern Hemisphere. Total prewhaling abundance exceeded 120,000, but by 1900 it was probably in the low thousands. In the U.S. western Arctic, 18,650 bowheads were killed by Yankee whalers between 1848 and 1914 from a population estimated at less than 20,000. The take by Alaska Eskimos has averaged 20-40 whales per year since 1914. The present population, 7,500, is about 40-60 percent of its 1848 carrying capacity. The stock has been increasing since commercial whaling ended and has increased 3.1 percent per year since 1978 (Figure IV-33).

iv. Gray Whale

Still listed under the Endangered Species Act (ESA) as endangered are the two stocks of north Pacific gray whales. The eastern north Pacific or "California" stock was heavily exploited by Yankee whalers in the last half of the 19th century. The present stock size, 21,113, is equal to or larger than the size of the 1846 population of 15,000-20,000. Population growth rate is 3.2 percent per year despite a Soviet subsistence catch of 167 whales per year (Figure IV-34).

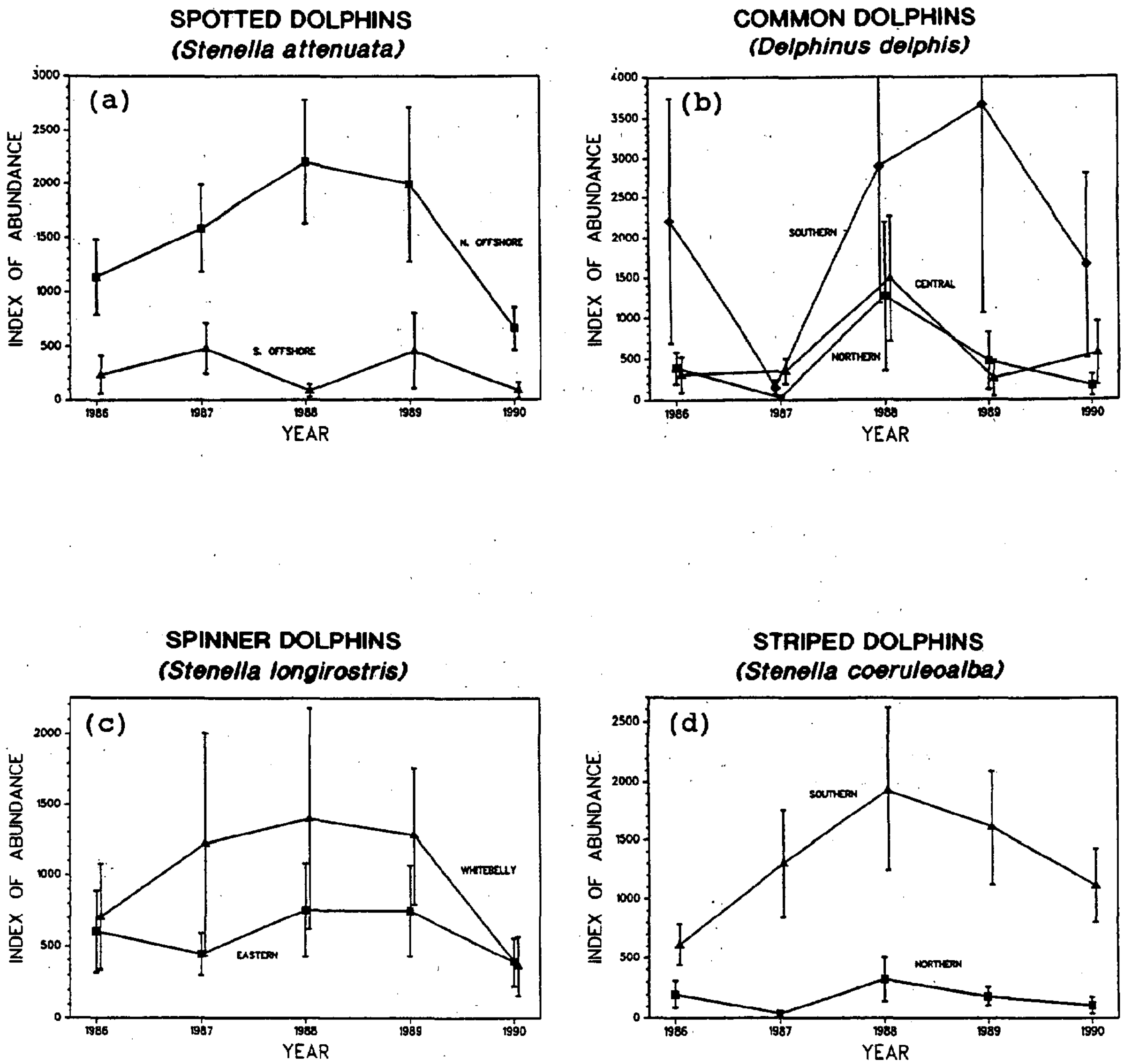


Figure IV-32 (a)-(d). Relative estimates of abundance for nine stocks of dolphins in the eastern tropical Pacific, 1986-90. (a) two stocks of spotted dolphins (Stenella attenuata), (b) three stocks of common dolphins (Delphinus delphis), (c) two stocks of spinner dolphins (Stenella longirostris), and (d) two stocks of striped dolphins (Stenella coeruleoalba). Error bars are one standard error. (Courtesy Tim Gerrodette and Paul Wade, Southwest Fisheries Science Center, NOAA National Marine Fisheries Service)

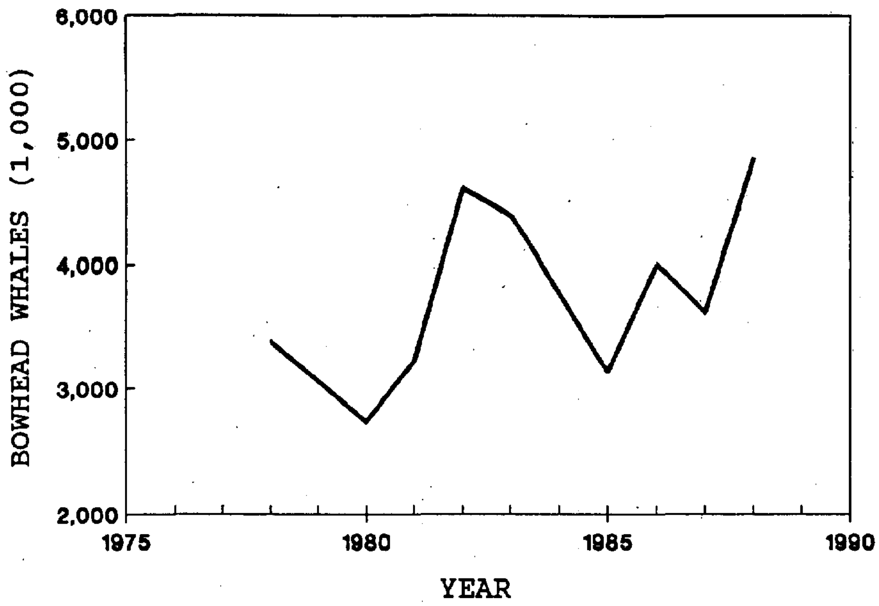


Figure IV-33. Actual count of bowhead whales, 1978-88. (Courtesy NOAA National Marine Fisheries Service)

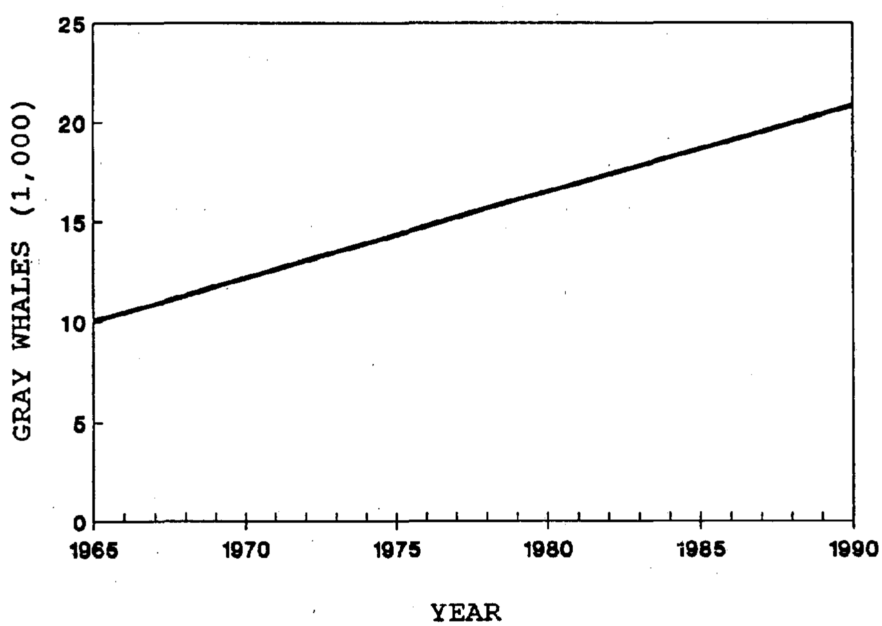


Figure IV-34. Estimated population of gray whales, 1965-90. (Courtesy NOAA National Marine Fisheries Service)

v. Steller Sea Lion

The northern or Steller sea lion, classified as threatened under the ESA, ranges coastal waters of the north Pacific Ocean from California to Japan. The species has declined sharply throughout its range in the last 20 years, and is now well below its optimum level. The number of adults and juveniles in U.S. waters crashed from 154,000 in 1960 to 42,000 in 1990. Most of this 73 percent decline occurred in Alaska waters (Figure IV-35). The decline in Alaska is believed to be a combination of incidental kills in fisheries, illegal shooting, changes in the numbers and/or quality of prey, and possibly other unidentified factors. The population off Washington and Oregon is low but stable at about 3,000, but in California they have slowly declined since the 1950s to about 2,000.

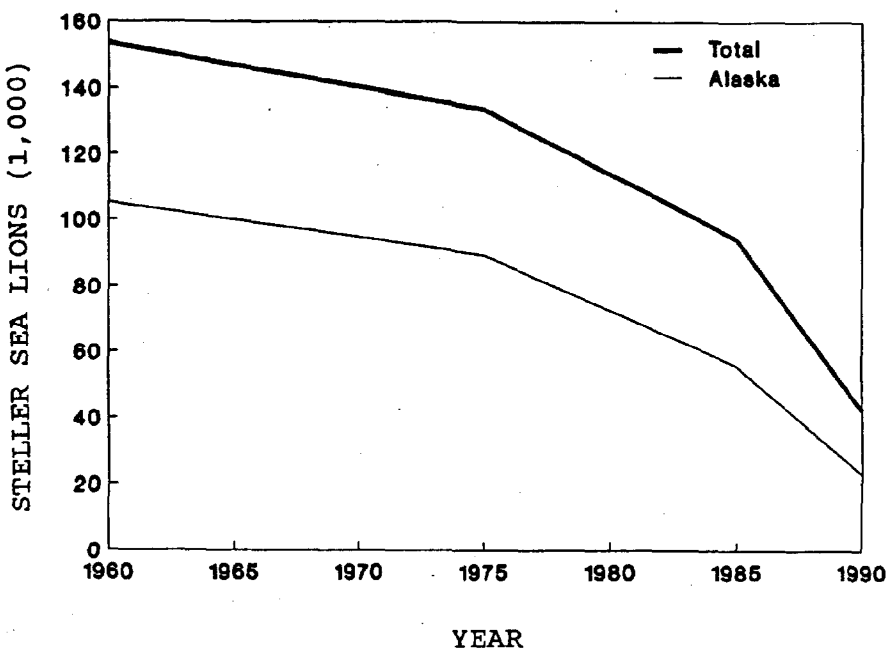


Figure IV-35. Estimated U.S. population of Steller sea lions and population trends in Alaska, 1960-90. (Courtesy NOAA National Marine Fisheries Service)

vi. Northern Fur Seal

The northern fur seal of the north Pacific Ocean, considered depleted under the Marine Mammal Protection Act (MMPA), ranges across subarctic Pacific Rim waters from California to Japan. It numbered 1.2 million in 1983 with 871,000 in U.S. waters. The major U.S. breeding population is on Alaska's Pribilof Islands of St. Paul and St. George. Production on the Pribilof Islands dropped more than 60 percent between 1955 and 1980, but has since been stable. On St. George Island production has continued to decline about 6 percent per year since 1970 (Figure IV-36). Small U.S. breeding populations are also found on Alaska's Bogoslof Island (1,500), and California's San Miguel Island (4,000). The Pribilof Islands' fur seal carrying capacity has changed little since the 1950s.

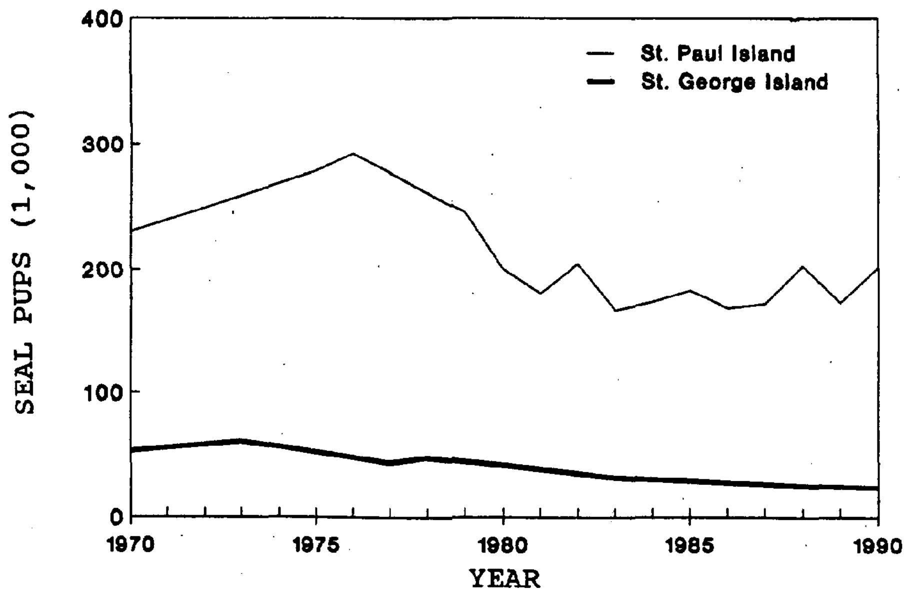


Figure IV-36. Northern fur seal pup counts on St. Paul and St. George Islands, Alaska, 1970-90. (Courtesy NOAA National Marine Fisheries Service)

vii. California Sea Lion

The California sea lion has three subspecies living on the U.S. west coast and British Columbia, in the Galapagos Islands, and in Japan. Between Mexico and British Columbia the population, about 157,000 animals, has grown about 6 percent per year since the 1970s (Figure IV-37). Annual production of 16,000-17,000 pups on the California Channel Islands in 1986 corresponds to a population size of about 87,000 animals. The California population in 1982 (prior to the 1982-83 El Nino warm water intrusion) was thought to be near or slightly below the lower end of its optimum population.

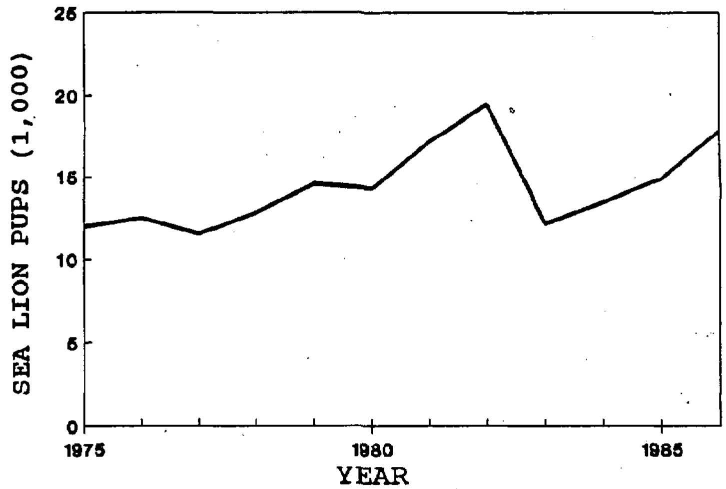


Figure IV-37. California sea lion pup counts on the Channel Islands, 1971-86. (Courtesy NOAA National Marine Fisheries Service)

viii. Hawaiian Monk Seal

Considered endangered under the ESA, the monk seal is limited to the small islands and atolls of the 1,100-mile Hawaiian Archipelago. The total population is about 1,500 animals, a 60 percent decline since 1958. The monk seals at French Frigate Shoals have recently shown a slight increase. Average counts of the five major breeding sites increased from 468 to 639 during 1983-87 but dropped to 546 in 1990. Production increased during 1983-88 but dropped 23 percent in 1990 from the 1983-88 average (Figure IV-38).

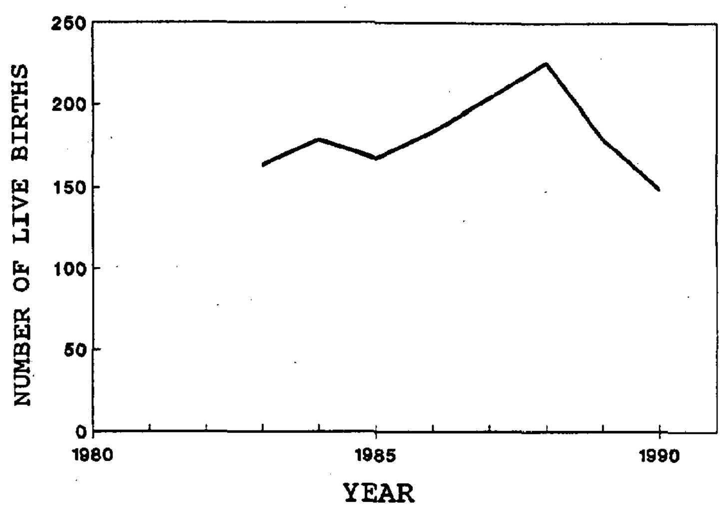


Figure IV-38. Hawaiian monk seal live births, 1983-90. (Courtesy NOAA National Marine Fisheries Service)

c. Habitat Conservation

The U.S. Army Corps of Engineers (COE) regulates wetland activities in waters of the United States under the authority of the Rivers and Harbors Act and the Clean Water Act. In this capacity, thousands of requests to alter wetlands are processed annually in the southeastern region of the United States alone. NMFS provides recommendations to the COE that are designed to minimize project effects on marine, estuarine, and anadromous fishery resources.

Because the amount, type, and geographical distribution of the habitat were generally unknown, the NMFS, Southeast Region, developed a computerized system in 1980 to compile such information. The effectiveness of the NMFS' habitat program also can be monitored and modifications can be made to the program as needed.

Since 1981 the NMFS Southeast Region has reviewed 39,050 projects involving wetlands and has collected detailed information on 9,148 of these (Table IV-5). These projects, for which there is detailed information, call for the alteration of 683,731 acres of wetlands. Mitigation of 176,536 acres involving creation of wetlands or enhancement of existing wetlands was also sought. If implemented, NMFS recommendations would have allowed 312,366 acres of alteration and potentially conserved 371,366 wetland acres. Most accepted alterations were for marsh management, maintenance dredging, and beach nourishment. Based on the nature of the work, the proposed mitigation, if successful, would exceed anticipated losses with regard to acreage considerations.

Table IV-5. NMFS Southeast Region habitat conservation efforts from 1981 to 1989. (Courtesy Andreas Mager, Jr., Southeast Region, NOAA National Marine Fisheries Service)

Year	No.	Acres Proposed by Applicants	Acres Accepted by NMFS	Acres Potentially Conserved	Acres Mitigated
81	811	7,949	2,868	5,081	2,471
82	1,059	81,184	21,831	59,353	7,910
83	825	20,778	8,658	12,120	26,775
84	888	8,606	3,981	4,625	54,050
85	1,802	65,670	11,161	54,509	19,200
86	969	90,559	70,838	19,721	49,713
87	1,054	21,755	8,135	13,620	7,139
88	977	359,876	173,284	186,592	1,827
89	763	27,354	11,610	15,745	7,451
=	9,148	683,731	312,366	371,366	176,536

(No. is number of projects sampled)

d. Marine Sanctuaries and Estuarine Research Reserves

NOAA is actively involved in the preservation of the nation's valuable marine and estuarine resources. Through two programs, the National Marine Sanctuary Program and the National Estuarine Research Reserve System, NOAA protects sensitive and ecologically important marine areas for their scientific, educational, historical, recreational, and aesthetic resources.

i. National Marine Sanctuary Program

In 1972, in response to a growing awareness of the intrinsic environmental and cultural value of the United States' coastal waters, Congress passed the Marine Protection, Research and Sanctuaries Act. The Act authorizes the Secretary of Commerce to designate discrete areas as national marine sanctuaries and to promote comprehensive management of their special resources. National Marine Sanctuaries may be designated in coastal and ocean waters, in submerged lands, and in the Great Lakes and their connecting waters. Under Title III of the Act, NOAA manages the National Marine Sanctuary Program. NOAA's mission is to develop a system of sanctuaries to promote research, education, and conservation. The National Marine Sanctuaries are administered by the Sanctuaries and Reserves Division of the National Ocean Service.

Nine National Marine Sanctuaries (NMS) have been designated since the program began (Figure IV-39), the newest being Florida Keys NMS. The NMSs are located in a number of distinct marine environments: nearshore, open water, benthic, and in temperate and tropical areas, and range from in size from less than one to over 1252 square nautical miles. Total area is almost 4.5 million acres. Five sanctuaries are located in or contain open water: Gulf of the Farallones, Channel Islands, Cordell Bank, Gray's Reef, and the MONITOR. The Channel Islands and the Gulf of the Farallones include islands, and the latter extends to the mainland. Three other sanctuaries are nearshore ecosystems in the tropical zone, with outstanding coral reefs and sea grass beds. On the Atlantic coast, Gray's Reef is a limestone, live bottom reef. The MONITOR NMS protects the wreckage of the famous Civil War ironclad. Table IV-6 shows the growth of the National Marine Sanctuary Program since 1975.

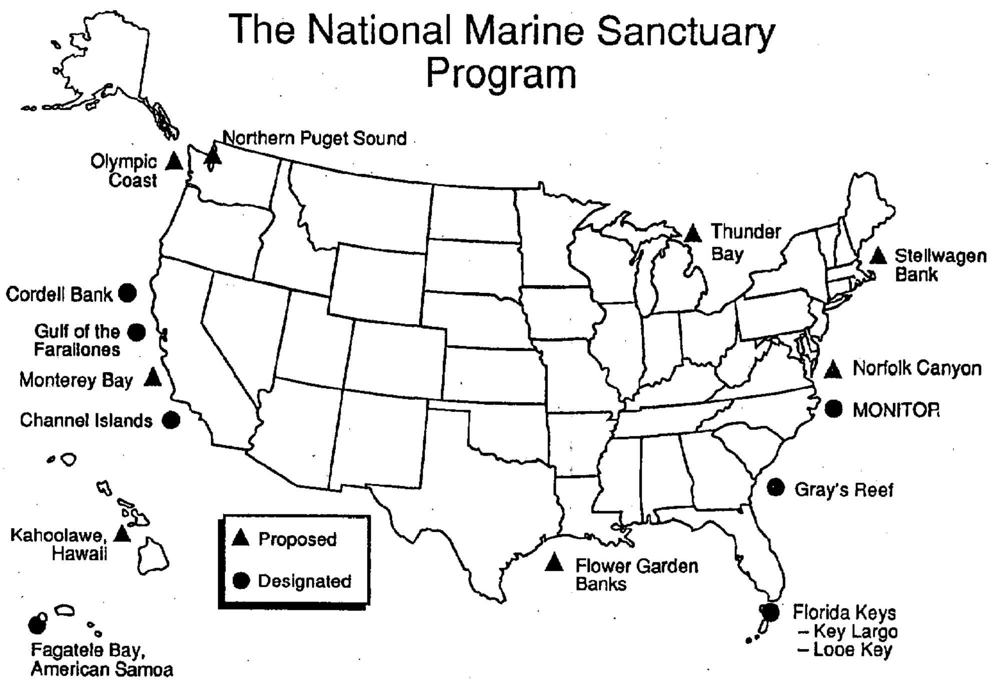


Figure IV-39. The National Marine Sanctuary Program. (Courtesy Sanctuaries and Reserves Division, NOAA National Ocean Service)

Table IV-6. National Marine Sanctuaries, 1975-1991. (Courtesy Sanctuaries and Reserves Division, NOAA National Ocean Service)

Year	Number	Area (acres)
1975	2	64,640
1976	2	64,640
1977	2	64,640
1978	2	64,640
1979	2	64,640
1980	3	865,920
1981	6	1,486,720
1982	6	1,486,720
1983	6	1,486,720
1984	6	1,486,720
1985	6	1,486,720
1986	7	1,487,360
1987	7	1,487,360
1988	7	1,487,360
1989	8	1,741,440
1990	9	4,412,480
1991	9	4,412,480

ii. National Estuarine Reserve Research System

As early as the 1960s Congress recognized the need to protect coastal resources from pollution and the pressures of development. In particular danger were the nation's estuaries, those valuable, yet fragile, areas where rivers meet the sea. To address threats to these critical areas, the National Estuarine Reserve Research System was established as part of the Coastal Zone Management Act of 1972. NOAA was given the responsibility for designating estuarine reserves and administering the System.

The goal of this program is to establish and manage, through federal-state cooperation, a national system of reserves representing different coastal and estuarine environments that exist in the United States and its territories. The reserves are natural laboratories in which studies are conducted on processes occurring within the estuaries. Nineteen reserves, protecting approximately 400,000 acres of estuarine lands and waters, are in the system (Figure IV-40). Education and research opportunities are available to qualified applicants. Table IV-7 sows the growth of the National Estuarine Reserve Research System since 1975.

Table IV-7. National Estuarine Reserve Research System, 1975-1991. (Courtesy Sanctuaries and Reserves Division, NOAA National Ocean Service)

Year	Number	Area (acres)
1975	1	4,700
1976	3	14,205
1977	3	14,205
1978	4	22,605
1979	5	216,383
1980	9	223,426
1981	11	229,652
1982	14	240,571
1983	14	240,571
1984	15	242,121
1985	15	242,121
1986	16	245,149
1987	16	245,149
1988	17	247,348
1989	18	253,477
1990	18	259,945
1991	19	399,302

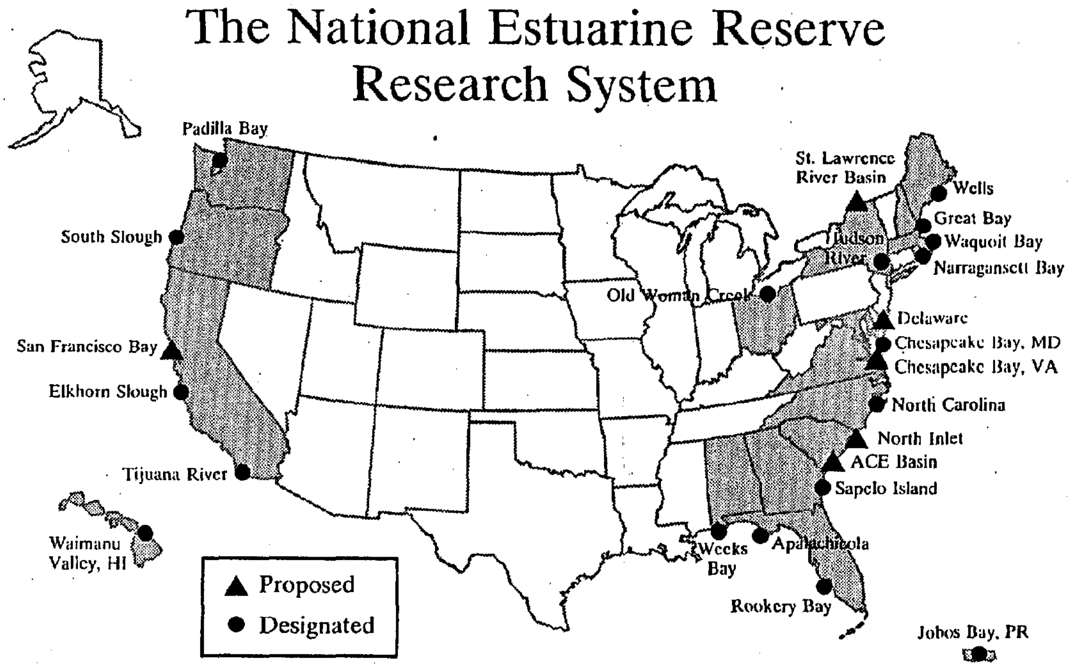


Figure IV-40. The National Estuarine Reserve Research System. (Courtesy Sanctuaries and Reserves Division, NOAA National Ocean Service)

ESTUARIES

Estuaries, among the planet's most productive natural systems, are important features of coastal regions. Biologically they form a transition zone between freshwater and marine ecosystems. Estuaries are defined as semi-enclosed bodies of water having a free connection with the open sea and within which seawater is diluted by freshwater drainage. The important role estuaries play in sustaining the health and abundance of fish, shellfish, and birds has long been recognized. Estuaries are a vital coastal habitat, particularly during early life stages of many animals. The freshwater and nutrients they provide produce a habitat critical to the health of our living resources. Estuaries are among the most densely populated and heavily used regions in the nation; an estimated 45 percent of our population now lives around these areas. Society places a high value on estuaries as places for living, working, and recreating.

The National Estuarine Inventory (NEI) is a series of projects within NOAA's National Ocean Service designed to define and characterize the nation's estuarine resource base and develop a national estuarine capability. NOAA began the NEI in 1983 and has produced four major NEI atlases, six national data bases, and numerous technical reports. The NEI contains information on the physical and hydrological features, population and land use, wetlands, and selected economic characteristics of 102 estuaries. The information presented in this section is only a sample of that available in NOAA's NEI data base.

a. North Atlantic

The North Atlantic estuarine region extends from the U.S.-Canadian border to Cape Cod. The regional estuaries account for more than 23,000 square miles of drainage. These estuaries were formed by glaciers that removed soil cover, leaving rocky shorelines and steep-sided river channels. Selected characteristics of North Atlantic estuaries are shown in Figure IV-41.

b. Middle Atlantic

The Middle Atlantic estuarine region extends from Buzzards Bay through Chesapeake Bay. Estuaries in this region account for more than 48,000 square miles of drainage. Middle Atlantic estuaries are geomorphologically different from those in the North Atlantic region. Rising sea level, resulting from melting glaciers, drowned the mouths of ancient rivers extending across the continental shelf. The result was the coastal plain estuaries of the Middle Atlantic Region. Selected characteristics of Middle Atlantic estuaries are shown in Figure IV-42.

c. South Atlantic

The South Atlantic estuarine region extends from North Carolina to Southern Florida. The estuaries in this region account for almost 56,000 square miles of drainage along the South Atlantic coast. South Atlantic estuarine regions are characterized by two general shoreline formations. The first is a low-lying, marshy shoreline with a pattern of tributaries flowing to the sea and is most prevalent along the South Carolina and Georgia coasts. The second is represented by lagoons bounded by extensive barrier island systems and is found in North Carolina and central Florida. An exception to this is the St. John's River, a large river with limited access to the sea, but tidally influenced a considerable distance upstream. Characteristics of South Atlantic estuaries are shown in Figure IV-43.

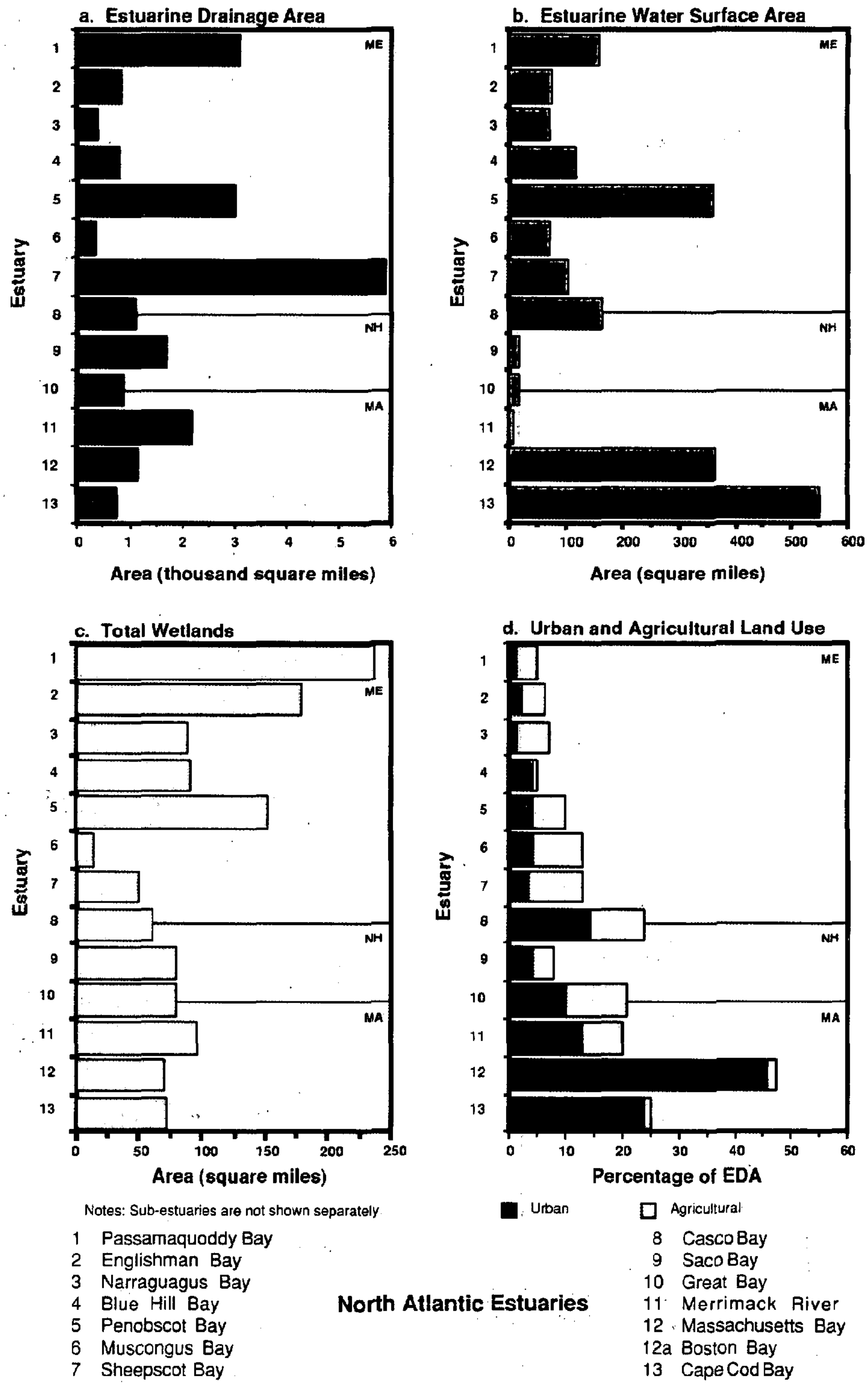
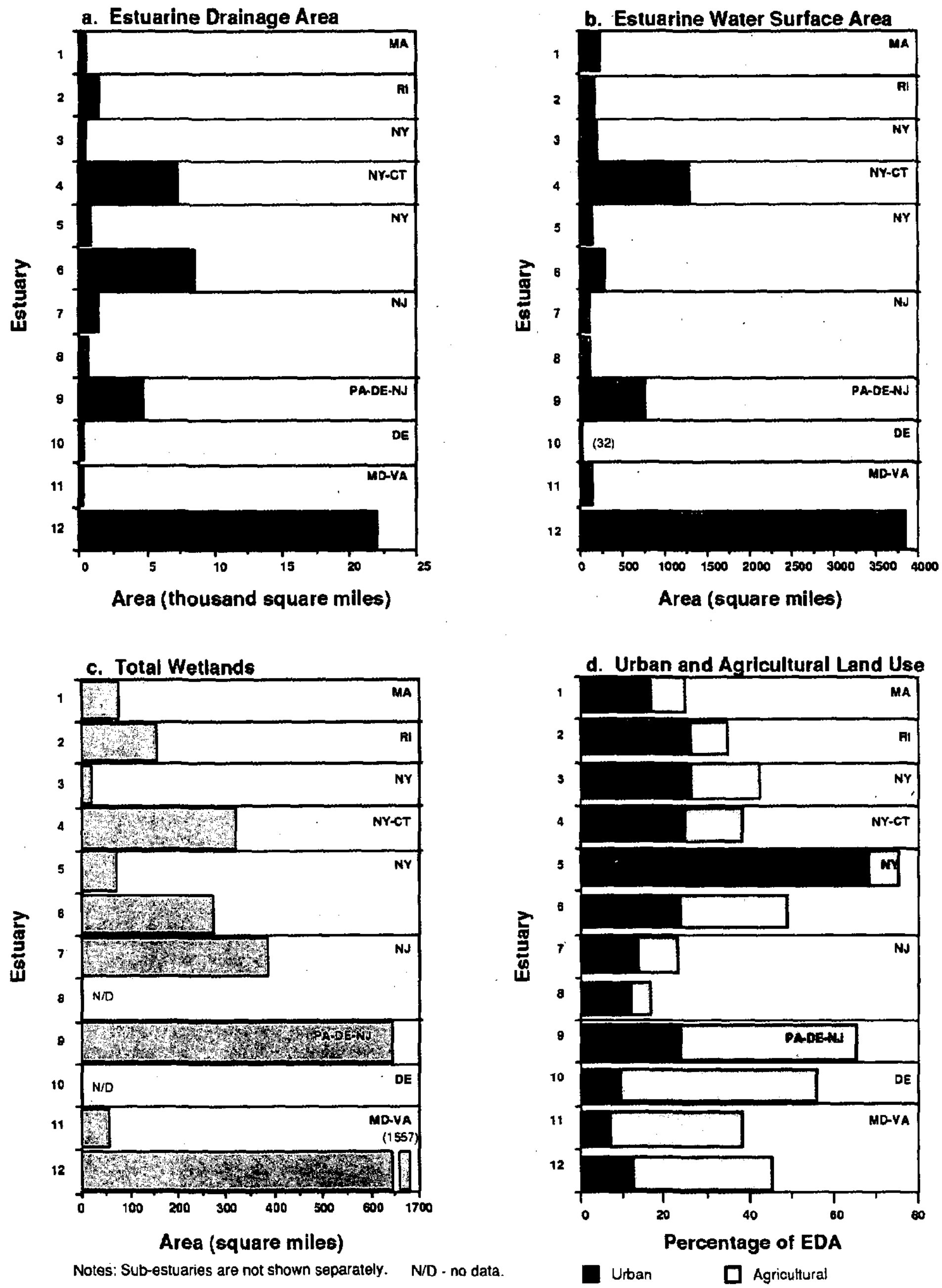


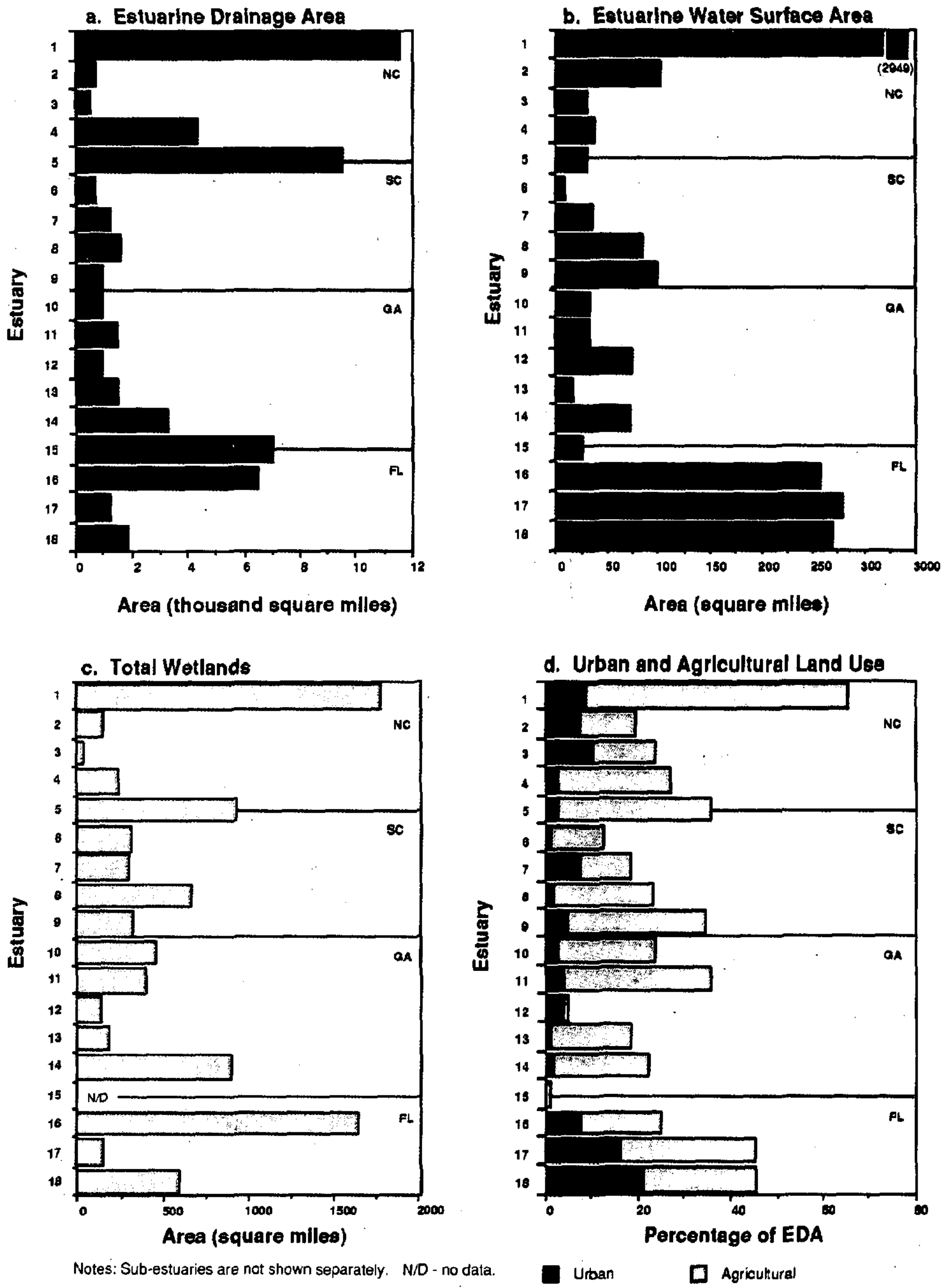
Figure IV-41 (a)-(d). Selected characteristics, North Atlantic estuaries. EDA= estuarine drainage area. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)



Middle Atlantic Estuaries

1 Buzzards Bay
2 Narragansett Bay
3 Gardiners Bay
4 Long Island Sound
4a Connecticut River
5 Great South Bay
6 Hudson River/Raritan Bay
7 Barnegat Bay
8 New Jersey Inland Bays
9 Delaware Bay
10 Delaware Inland Bays
11 Chincoteague Bay
12 Chesapeake Bay
12a Patuxent River
12b Potomac River
12c Rappahannock River
12d York River
12e James River
12f Chester River
12g Choptank River
12h Tangier/Pocomoke Sounds

Figure IV-42 (a)-(d). Selected characteristics, Middle Atlantic estuaries. EDA= estuarine drainage area. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)



South Atlantic Estuaries

1 Albemarle/Pamlico Sounds
1a Pamlico/Pungo Rivers
1b Neuse River
2 Bogue Sound
3 New River
4 Cape Fear River
5 Winyah Bay
6 North/South Santee Rivers
7 Charleston Harbor
8 St. Helena Sound
9 Broad River
10 Savannah River
11 Ossabaw Sound
12 St. Catherines/Sapelo Sounds
13 Altamaha River
14 St. Andrew/St. Simons Sounds
15 St. Marys River/Cumberland Sound
16 St. Johns River
17 Indian River
18 Biscayne Bay

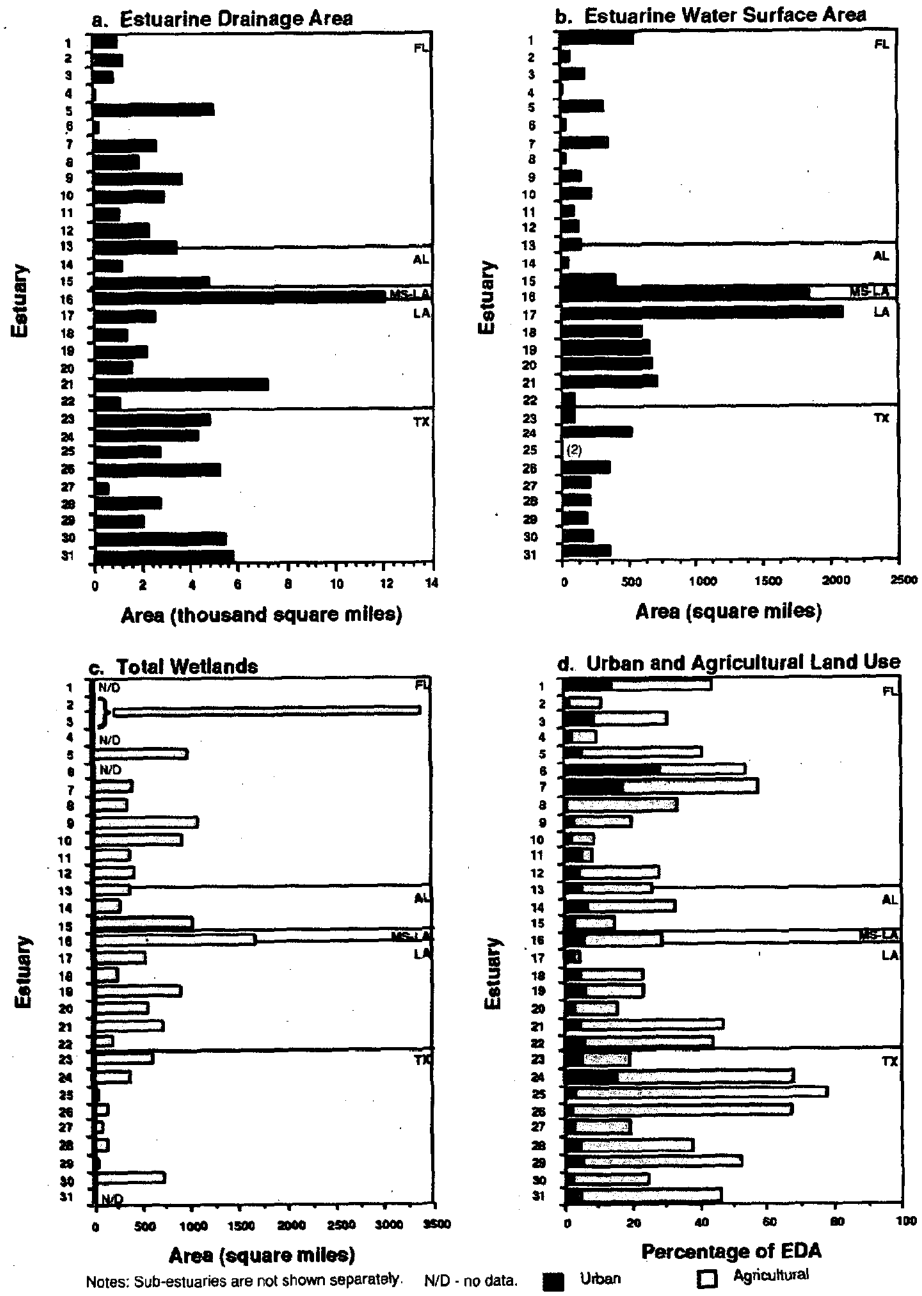
Figure IV-43 (a)-(d). Selected characteristics, South Atlantic estuaries. EDA= estuarine drainage area. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)

d. Gulf of Mexico

The Gulf of Mexico estuarine region extends from the southern tip of Florida west to the Texas-Mexico border. The estuaries in this region account for more than 96,000 square miles of drainage along the Gulf of Mexico coast. Like the South Atlantic and much of the Middle Atlantic, the Gulf of Mexico is part of a vast coastal plain of sedimentary deposits. Major features include the Mississippi and Atchafalaya deltas, where large amounts of land-derived sediments have been deposited in shallow coastal waters. This delta environment forms a complex web of estuarine channels and extensive coastal wetlands, important habitat for many recreational and commercial fisheries. In other areas, sediment transported and deposited by oceanic currents formed offshore bars enclosing shallow, and sometimes extensive bodies of water. Such estuaries are common along the Texas shoreline. Gulf of Mexico estuarine characteristics are shown in Figure IV-44.

e. Pacific Coast

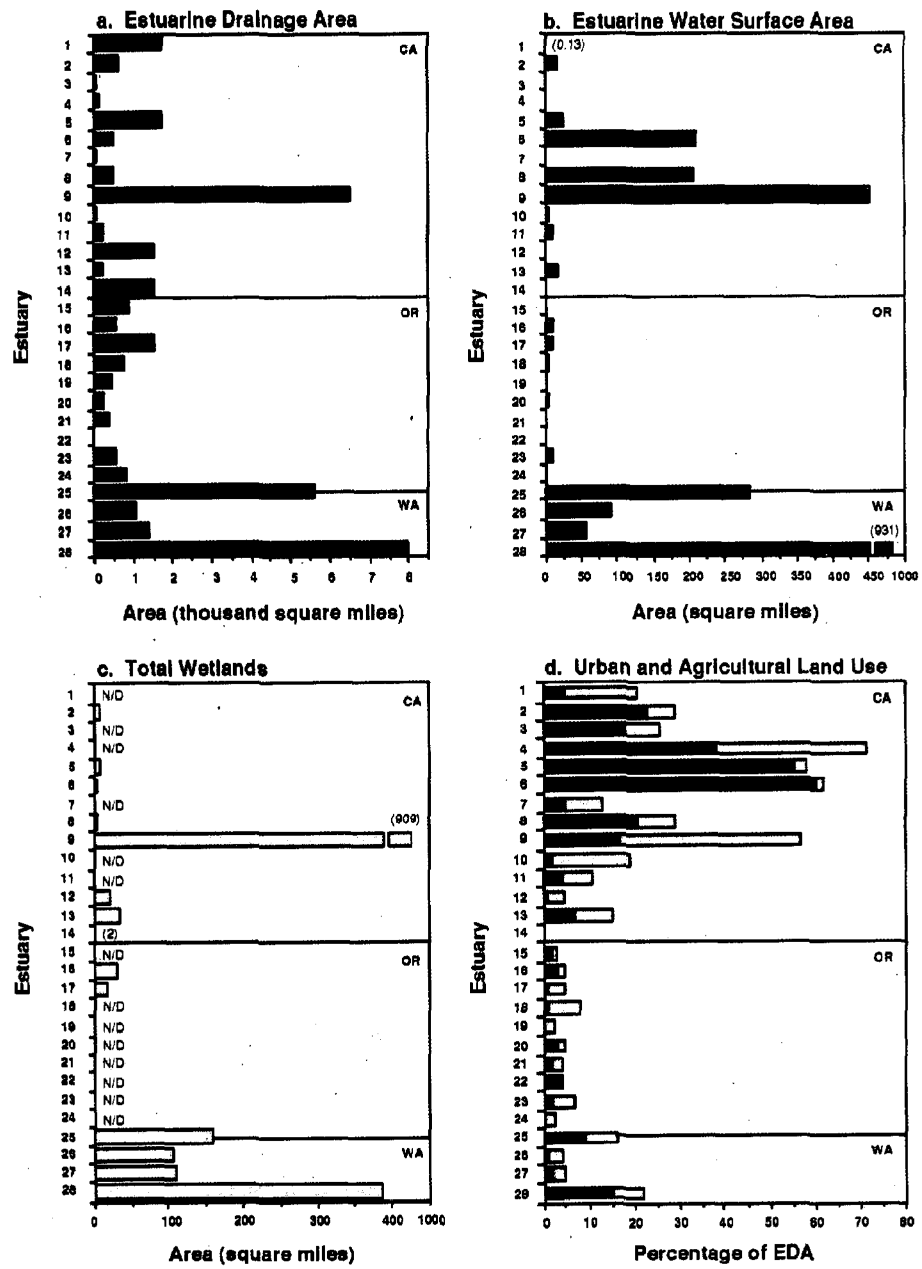
The Pacific estuarine region extends from Tijuana Estuary to Puget Sound. Estuaries in this region account for almost 38,000 square miles of drainage along the Pacific coast. The Pacific coast is characterized by uniformly uplifted, resistent rock, except for coastal flats and islands along parts of the Washington coast. Coastal mountain formations have restricted the area of low-lying coastal plains and rivers that flow toward the sea resulting in narrow, deep, and steep-sided estuaries. The large estuaries of San Francisco Bay and Puget Sound formed when sections of the continent sank below sea level due to active mountain building. In Puget Sound, additional deepening and elongation occurred due to glacial activity. Because of the unique regional geomorphology (deep submarine canyons in Southern California bays and shallow coastal estuaries in Oregon), the average depth and volume of the bays and estuaries vary considerably. Santa Monica Bay, Monterey Bay, and Puget Sound are among the deepest in the nation whereas Oregon estuaries are among the most shallow. Characteristics of Pacific coast estuaries are shown in Figure IV-45.



Gulf of Mexico Estuaries

1 Florida Bay
2 South Ten Thousand Islands
3 North Ten Thousand Islands
4 Rookery Bay
5 Charlotte Harbor
5a Caloosahatchee River
6 Sarasota Bay
7 Tampa Bay
8 Suwannee River
9 Apalachee Bay
10 Apalachicola Bay
11 St. Andrew Bay
12 Choctawhatchee Bay
13 Pensacola Bay
14 Perdido Bay
15 Mobile Bay
16 Mississippi Sound
16a Lake Borgne
16b Lake Pontchartrain
17 Breton/Chandeleur Sounds
18 Mississippi River
19 Barataria Bay
20 Terrebonne/Timbalier Bays
21 Atchafalaya/Vermilion Bays
22 Calcasieu Lake
23 Sabine Lake
24 Galveston Bay
25 Brazos River
26 Matagorda Bay
27 San Antonio Bay
28 Aransas Bay
29 Corpus Christi Bay
30 Upper Laguna Madre
30a Baffin Bay
31 Lower Laguna Madre

Figure IV-44 (a)-(d). Selected characteristics, Gulf of Mexico estuaries. EDA= estuarine drainage area. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)



Notes: Sub-estuaries are not shown separately. N/D - no data. ■ Urban □ Agricultural

Pacific Estuaries

1 Tijuana Estuary
2 San Diego Bay
3 Mission Bay
4 Newport Bay
5 San Pedro Bay
5a Alamitos Bay
5b Anaheim Bay
6 Santa Monica Bay
7 Morro Bay
8 Monterey Bay
8a Elkhorn Slough
9 San Francisco Bay
9a Central San Francisco San Pablo/Suisun Bays
10 Drakes Estero
11 Tomales Bay
12 Eel River
13 Humboldt Bay
14 Klamath River
15 Rogue River
16 Coos Bay
17 Umpqua River
18 Siuslaw River
19 Alsea River
20 Yaquina Bay
21 Siletz Bay
22 Netarts Bay
23 Tillamook Bay
24 Nehalem River
25 Columbia River
26 Willapa Bay
27 Grays Harbor
28 Puget Sound
28a Hood Canal
28b Skagit Bay

Figure IV-45 (a)-(d). Selected characteristics, Pacific estuaries. EDA= estuarine drainage area. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)

COASTAL WETLANDS

The nation's coastal wetlands are important natural resources. Wetlands form the interface between terrestrial and aquatic systems. They provide critical habitat for fish, shellfish, and wildlife. They also filter and process agricultural and industrial wastes, and buffer coastal areas against storm and wave damage. Our wetlands generate large revenues from a wide variety of recreational activities, such as fishing and hunting.

Wetland loss is occurring due to a number of reasons including urbanization, agriculture, oil exploration, sea level rise, and shoreline erosion. Nationally, more than 11 million acres of wetlands have been lost over the past 25 years due to human activity and natural processes. Although most of the losses have occurred in inland areas, coastal wetlands have also declined at an alarming rate over this period. For example, in the Chesapeake Bay region, losses of coastal wetlands are estimated at 6 percent annually.

Development of the National Coastal Wetlands Inventory was initiated by NOAA in 1986 and is conducted by the Strategic Environmental Assessments Division, Office of Ocean Resources, Conservation, and Assessment, National Ocean Service. The purpose of the inventory is to develop a comprehensive national coastal wetlands data base to increase our knowledge of the distribution and areal extent of wetlands and to improve our understanding and management of this vital resource. The data developed from this project is part of NOAA's National Estuarine Inventory (NEI).

The wetlands data are derived entirely from National Wetlands Inventory (NWI) maps produced by the U.S. Fish and Wildlife Service. The numerous wetland habitat types identified in these maps were aggregated into 4 major habitat types (salt marsh, fresh marsh, tidal flats, and forested and scrub-shrub).

a. New England

The coast of New England extends from the U.S. Canadian border Cape Cod and along the coasts of Rhode Island and Connecticut. The amount of coastal wetlands in the New England region is small. This is due to the rugged relief, rocky shorelines, and steep-sided river channels of the region, and incomplete data for the inland portions of most estuarine drainage areas. For the wetlands analysis, the NOAA NEI identified 16 estuaries along the New England coast. A total of 412 NWI maps were sampled in New England, encompassing nearly 1.5 million acres of wetlands.
Maine, having the largest land area sampled, also contained the most wetlands, approximately 49 percent of the total wetlands sampled in the region, followed by Massachusetts (31 percent), Connecticut (10 percent), New Hampshire (6 percent), and Rhode island (4 percent) (Figure IV-46). Forested wetlands were the most

common wetland type in the region, accounting for approximately 79 percent of the total wetlands, followed by tidal flats (10 percent), salt marsh (6 percent), and fresh marsh (5 percent).

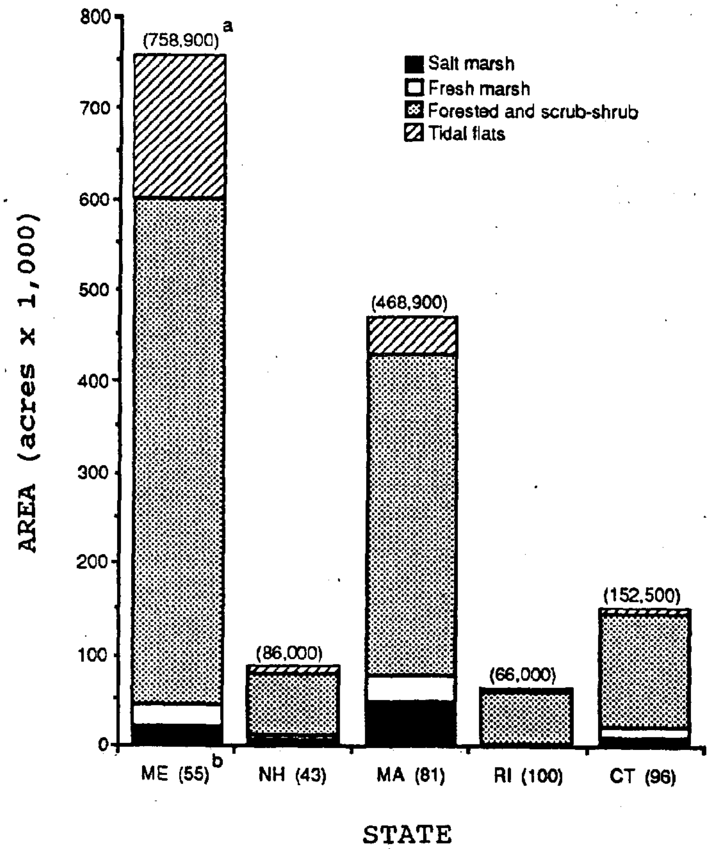


Figure IV-46. New England region coastal wetland acreage by state. Value in ()[a] is total wetland acerage. Value in ()[b] is percent of state sampled. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)

b. Mid-Atlantic

The Mid-Atlantic study area extends from Long Island, New York, southwest to New Jersey and Delaware, then south to Virginia and the Delmarva Peninsula. Eight estuaries are identified in this region. A total of 735 NWI maps, covering 23.4 million acres, were sampled by NOAA for the Mid-Atlantic region. Approximately 11 percent, or 2.4 million acres, were identified as wetlands. Forested wetlands were the most common habitat type in the Mid-Atlantic, accounting for nearly 58 percent of the region's total wetlands, followed by saltmarsh (28 percent), tidal flats (10 percent), and fresh marsh (4 percent).

New Jersey, Virginia, and Maryland dominated the wetlands of the region, accounting for 85 percent of the regional total (Figure IV-47). Virginia contained the largest grid-sampled area with 39 percent of the total Mid-Atlantic area sampled. Maryland and New Jersey followed with 21 and 20 percent of the total. New York was next with only 9 percent of the total, followed by Delaware (6 percent), Pennsylvania (5 percent), and the District of Columbia (< 1 percent). Virginia had the region's largest amount of both tidal flats and fresh marsh, accounting for 43 and 35 percent respectively of the regional total of each habitat. New Jersey contained the most forested wetlands in the region (37 percent of the regional total), and Maryland contained the most salt marsh (30 percent of the regional total). Due to its size, Delaware contained fewer wetlands than New Jersey, Virginia, or Maryland. However, 17 percent of the total area sampled in Delaware was wetlands, second only to New Jersey with 18 percent. Forested wetlands dominated those areas grid-sampled in Pennsylvania, accounting for 76 percent of the state wetland total. Thirty-six percent of those wetlands sampled in New York were tidal flats.

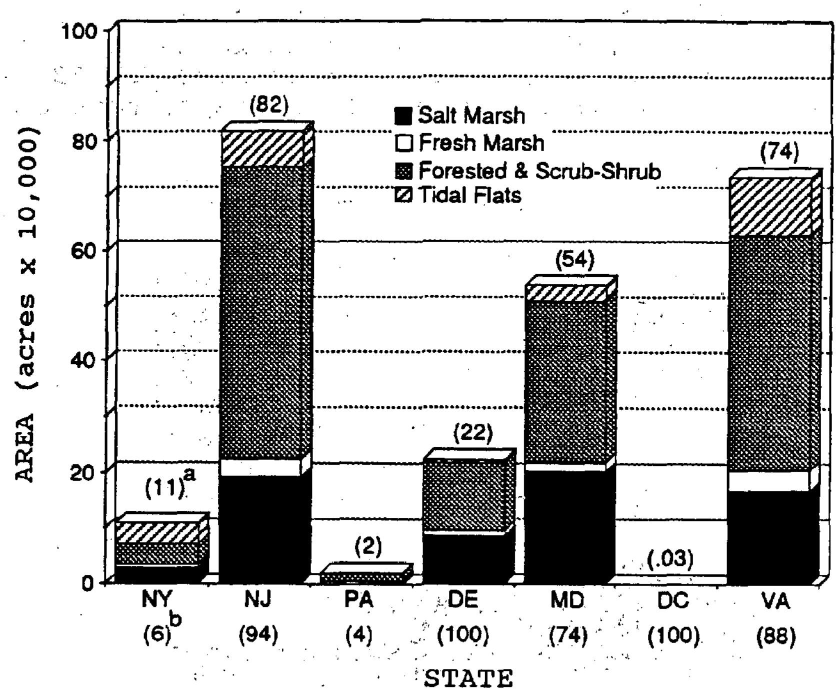


Figure IV-47. Mid-Atlantic coastal wetland acreage of four wetland types by state. Value in ()[a] is total wetland acreage. Value in ()[b] is percent of state sampled. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)

c. Gulf of Mexico

The Gulf of Mexico region extends from the southern tip of Florida west to the Texas/Mexico border. The U.S. portion of the Gulf of Mexico encompasses 5 states (Texas, Louisiana, Mississippi, Alabama, Florida) and 23 estuarine drainage areas. A total of 1,543 NWI maps covering 56.2 million acres were sampled by NOAA for the Gulf of Mexico.

Of the 6 states in the region, Florida contained the most wetlands (50 Percent of the total), followed by Louisiana (24 percent), Texas (12 percent), Alabama (8 percent), Mississippi (5 percent), and Georgia (<1 percent) (Figure IV-48). Texas and Florida contained the largest grid sampled areas with 37 and 35 percent of the total Gulf area sampled respectively. Louisiana accounted for only 14 percent of the total due to poor map availability, followed by Alabama (8 percent), Mississippi (6 percent), and Georgia (<1 percent). The central-to-eastern portions of the Gulf (Mississippi, Alabama, Florida) were dominated by forested wetlands, accounting for over 83 percent of the forested total for the entire Gulf. The coastal areas of the western Gulf (Texas, Louisiana) were dominated by salt marsh having 86 percent of the regional total, with the highest concentrations in Louisiana (69 percent). Texas also contained the largest amount of tidal flats in the Gulf accounting for over 54 percent of the total, while Florida contained 38 percent. Fresh marsh is found throughout the Gulf of Mexico with its greatest abundance in Florida (53 percent) followed by Louisiana and Texas (26 and 20 percent, respectively).

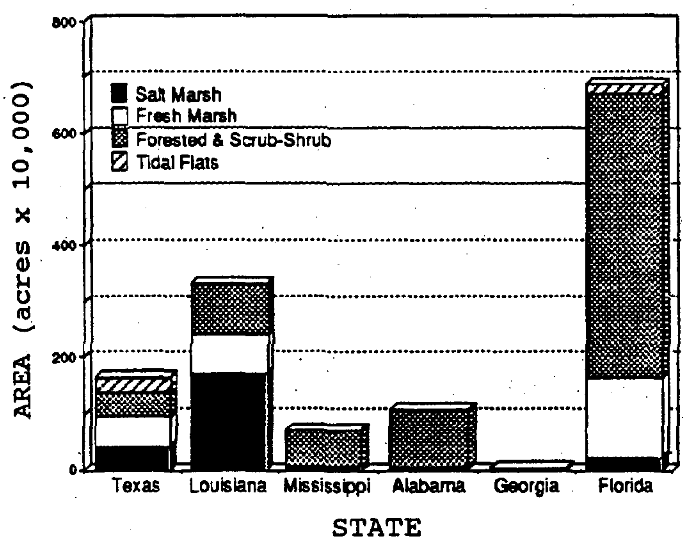


Figure IV-48. Gulf of Mexico region coastal wetland acreage for four wetland types by state. (Courtesy Strategic Environmental Assessments Division, NOAA National Ocean Service)

d. West Coast

The west coast of the contiguous U.S. extends from the Canadian border near Puget Sound, Washington, south through Oregon to Cape Mendicino, California, and southeast to San Diego and the Mexican border. For this analysis, the NOAA NEI identifies 14 estuaries along the west coast. A total of 1,525 NWI maps, covering 55.7 million acres, were sampled by NOAA in the west coast region. Approximately 2.5 percent, or 1.4 million acres, were identified as wetlands. Forested wetlands were the most common wetland habitat type found in the region (55 percent of the total wetlands), followed by fresh marsh (21 percent), tidal flats (15 percent), and salt marsh (9 percent).

California contained more wetlands than any other state in the region (56 percent), followed by Washington (28 percent) and Oregon (16 percent) (Figure IV-49). California also contained the largest grid-sampled area with 49 percent of the total west coast area sampled. Oregon followed with 27 percent and Washington with 24 percent. Only 3 percent of the area sampled in both California and Washington was wetlands, and only slightly over 1 percent of the total area sampled in Oregon was wetlands. Coastal wetland abundance on the west coast is considerably less than along other U.S. coasts. For example, in the Gulf of Mexico, Louisiana has over 45 percent of its total grid-sampled area (over 3.3 million acres) identified as wetlands.

California contained the region's largest amounts of salt marsh, forested wetlands, and tidal flats with 75, 63, and 47 percent of the region's total, respectively. Washington contained the region's largest amounts of fresh marsh (39 percent). Oregon contained varying amounts of each wetland type, with forested wetlands dominating and accounting for 45 percent of the state total. California and Washington were also dominated by forested wetlands accounting for 62 and 47 percent, respectively, of each state's wetland total.

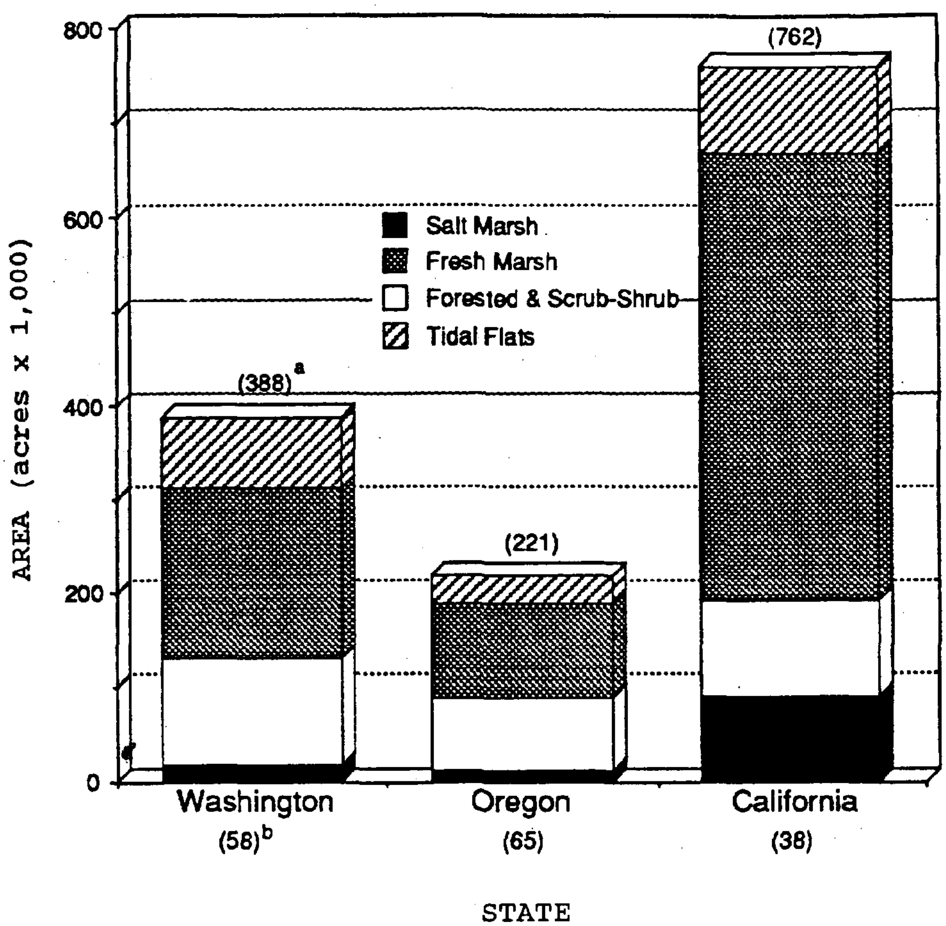


Figure IV-49. West Coast coastal wetland acreage of four wetland types by state. Value in ()[a] is total wetland acreage. Value in ()[b] is percent of state sampled. (Courtesy Strategic Environmental Assessment Division, NOAA National Ocean Service)

VEGETATION INDEX

During the last decade, NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) has been collecting measurements of the global vegetation cover using the Advanced Very High Resolution Radiometer (AVHRR) onboard NOAA's polar orbiting satellites. The principle used in defining vegetation indices is based on the discontinuity of the reflectance for green vegetation. Since green vegetation is highly absorbent to incoming radiation in the visible part of the spectrum and reflects in the near-infrared (IR), the calculation of an index of "greenness" for the vegetative surface is possible. The contrast between the near-infrared and visible AVHRR channel radiances has therefore been used effectively as an indicator of the density and state of the vegetative cover.

The commonly used parameter in this analysis of vegetation is the Normalized Difference Vegetation Index (NDVI). The NDVI is the difference between the near-IR and visible reflectances normalized by their sum. As an example of this technique, the seasonal variability of the NDVI and brightness temperature for an area in northeast Thailand is shown in Figure IV-50. The data used are from AVHRR global data with sampling of one 4 kilometer (km) pixel per 30 km map cells. These data were screened for cloud contamination and averaged over a 250 km by 250 km area for each month. The variability of NDVI and temperature is out of phase since the greenness reaches its maximum at the end of the rainy season, whereas the temperature peaks in the middle of the dry season. Research is underway at NESDIS to determine if such time series data can be used for routine climate monitoring.

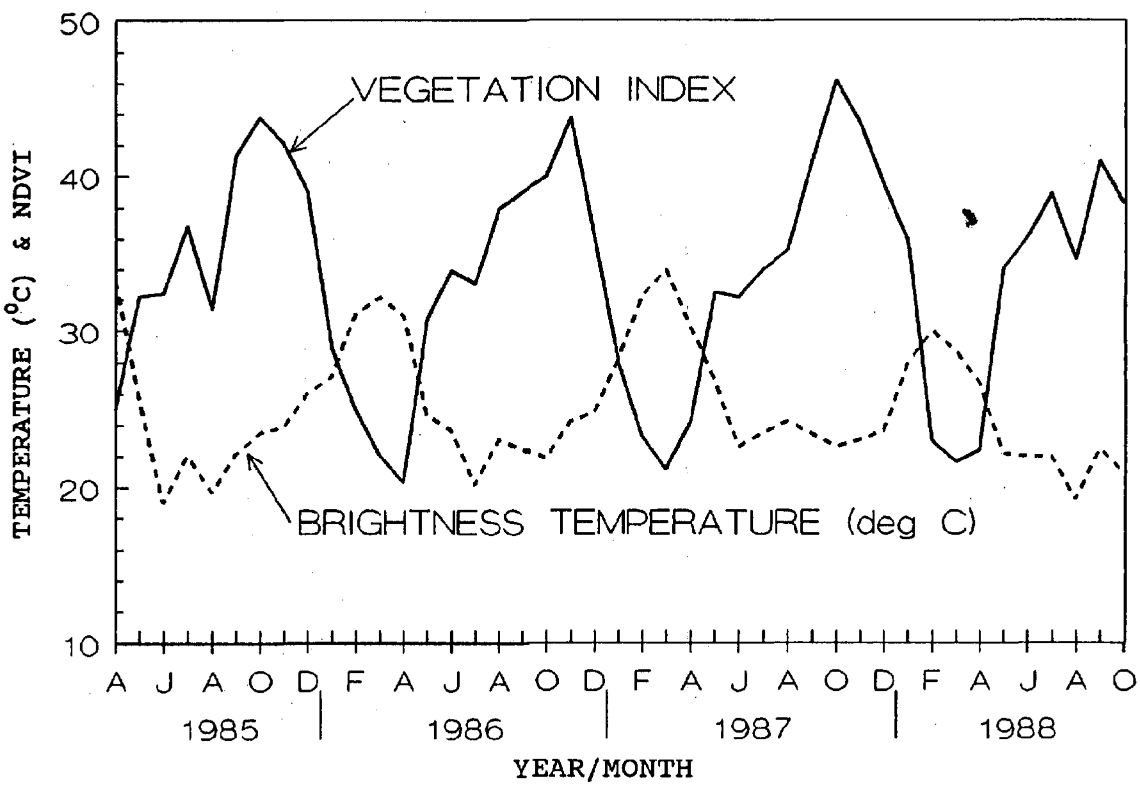


Figure IV-50. Normalized Difference Vegetation Index (NDVI) and brightness temperature for tropical wet-and-dry (monsoon) climate, northeast Thailand (15°N, 103°E). (Courtesy Garik Gutman, Satellite Research Laboratory, NOAA Environmental Satellite, Data, and Information Service)

APPENDICES

APPENDIX A: CONTRIBUTORS

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Thomas P. O'Connor, Coastal Monitoring and Bioeffects Assessment Division, NOAA National Ocean Service, WSC-1, Room 312, 6001 Executive Blvd., Rockville, MD 20853; (301) 443-

James T. Peterson, Deputy Director, Climate Modeling and Diagnostics Laboratory, NOAA Office of Oceanic and Atmospheric Research, 325 Broadway St., Boulder, CO 80303; (303) 497-6074; for trace gases

Walter G. Planet, Satellite Research Laboratory, NOAA National Environmental Satellite, Data, and Infirmation Service, WWBG, Room 810, 5200 Auth Rd., Camp Springs, MD 20233; (301) 763-8136; for global ozone

David R. Rodenhuis, Director, Climate Analysis Center, NOAA National Weather Service, WWBG, Room 606, 5200 Auth Rd., Camp Springs, MD 20233; (301) 763-8167; for climate assessment

Glenn D. Rolph, Air Resources Laboratory, Office of Oceanic and Atmospheric Research, SSMC-2, Room 9358, 1325 East-West Highway, Silver Spring, MD 20910; (301) 427-7684; for precipitation chemistry

Kenneth Sherman, Chief, Ecosystems Dynamics Branch, Northeast Fisheries Science Center, NOAA National Marine Fisheries Service, 28 Tarzwell Dr., Narragansett, RI 02882-1199: (401) 789-3210; for zooplankton, marine ecosystem dynamics

Eric Slaughter, Strategic Environmental Assessments Division, NOAA National Ocean Service, WSC-1, 6001 Executive Blvd., Room 305, Rockville, MD 20853; (301) 443-8553; for shellfish

John M. Steger, Satellite Applications Laboratory, NOAA National Environmental Satellite, Data, and Information Service, WWBG, Room 601, 5200 Auth Rd., Camp Springs, MD 20233; (301) 763-8282; for Atlantic Ocean long waves

Alan E. Strong, Satellite Applications Laboratory, NOAA National Environmental Satellite, Data, and Information Service, c/o Cooperative Project in Oceanic Remote Sensing. U.S. Naval Academy, Annapolis, MD 21402; (410) 267-3561; for remotely-sensed sea surface temperature

Wendy G. Teas, Miami Laboratory, NOAA National Marine Fisheries Service, 75 Virginia Beach Dr., Miami Beach, FL 33149; (305) 361-4276; for sea turtle strandings and marine turtle fibropapilloma

Kirk Thoning, Climate Monitoring and Diagnostics Laboratory, NOAA Office of Oceanic and Atmospheric Research, 325 Broadway St., Boulder, CO 80303; (303) 497-6650; for carbon dioxide

Donna D. Turgeon, Coastal Monitoring and Bioffects Assessment Division, NOAA National Ocean Service, WSC-1, Room 312, 6001 Executive Blvd., Rockville, MD 20853; (301) 443-8655; for contaminants in sediments and bivalve molluscs

Louis W. Uccellini, Chief, Meteorological Operations Division, National Meteorological Center, NOAA National Weather Service, WWBG, Room 410, 5200 Auth Rd., Camp Springs, MD 20233; (301) 763-8097; for winter storms

Usha S. Varanasi, Director, Environmental Conservation Division, Northwest Fisheries Science Center, NOAA National Marine Fisheries Service, 2725 Montlake Blvd. E., Seattle, WA 98112-2097; (206) 553-7737; for contaminants and biological effects in marine organisms

Paul R. Wade, Southwest Fisheries Science Center, NOAA National Marine Fisheries Service, P.O. Box 271, La Jolla, CA 92038; (619) 546-7000; for marine mammals

Austin J. Yeager. Director, Coast and Geodetic Survey, NOAA National Ocean Service, WSC-1, Room 1006, 6001 Executive Blvd., Rockville, MD 20852; (301) 443-8204; for coastal geodesy, nautical charting, aeronautical charting

David B. Zilkoski, Coast and Geodetic Survey, NOAA National Ocean Service, 11400 Rockville Pike, Room 313, Rockville, MD 20853; (301) 443-8567; coastal geodesy, subsidence

APPENDIX B: SOURCES OF ADDITIONAL INFORMATION IN NOAA
(In order of appearance in NOAA Environmental Digest)

Parameter	NOAA Source Code*
Air Temperature & Moisture	ARL, AWS, CAC, CMDL, NCDC, RCC, SAL, SDSD, SRL, SSD
Trace Gases	AL, ARL, CAC, CMDL, SAL, SDSD, SRL, SSD
Hydrological Cycle	AWS, CAC, HRL, NCDC, RCC, SAL, SDSD, SSD
Atmospheric Deposition	ARL
Solar Activity	NGDC, SEL
Earth's Radiation Budget	ARL, CMDL, SRL
Severe Weather	NCDC, NSSL, NHC, NMC, RCC, SAL
Southern Oscillation	AOML, CAC, CMDL, GFDL
Ocean Temperature	AOML, CAC, COAP, NEFC, NODC, OPC, PMEL, SDSD, SRL, SWFC
Salinity	COAP, NODC
Sea Level	GSL, NODC, OLLD
Quasi-Biennial Oscillation	AOML, ARL, CAC
Southern Oscillation	CAC, CMDL, GFDL
Ocean Transport	AOML, PMEL
Coastal Upwelling	PFEG, SDSD, SAL
Long Waves	SAL
Coastal Geodesy/Hydrography	CGS
Sea Ice	CAC, JIC, NSIDC, OPC, SAL, SDSD, SSD
Snow Cover	CAC, NSIDC, SAL, SDSD, SSD

	SDSD, SSD
Snow Cover	CAC, NSIDC, SAL, SDSD, SSD
Fisheries	AFC, FSD, NEFC, NWFC, SEFC, SWFC
Zooplankton	AFC, NEFC, NWFC, SEFC, SWFC
Shellfish	SEAD
Contaminants	CMBAD, ECD
Protected Resources	AFC, NEFC, NMML, OPR, SEFC, SWFC, SRD
Estuaries	SEAD
Coastal Wetlands	SEAD
Vegetation Index	CAC, SRL

* See following pages for definitions.

AFC Alaska Fisheries Science Center
NOAA National Marine Fisheries Service
7600 Sand Point Way, N.E.
BIN 1C15700 - Bldg. 4
Seattle, WA 98115-0070
(206) 526-4000, FTS 392-4000

The Science and Research Director, Alaska Region, and the staff of the Alaska Fisheries Science Center are responsible for conducting multidisciplinary research to provide fisheries management information to support national and regional programs of NMFS, and to respond to the needs of Regional Fishery Management Councils and other constituencies. The staff develops the scientific base required for status of stocks and status of fisheries reports, environmental assessment and environmental impact statements for management plans and/or international negotiations; and it pursues research to answer specific needs in the subject areas of habitat conservation, aquaculture, fishery development, fishery oceanography, food science, fishery economics, and fishery utilization.

AL Aeronomy Laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
325 Broadway St.
Boulder, CO 80303
(303) 497-3218, FTS 320-3218

The Aeronomy Laboratory conducts research on chemical and physical processes in the Earth's atmosphere to advance the capability of monitoring, predicting, and controlling the atmosphere. The research concentrates on the stratospheric and tropospheric regions of the atmosphere, but also involves the ionosphere, and occasionally the magnetosphere, as well as the atmosphere of other planets. The research methods employed involve both <u>in situ</u> and remote measurement of critical atmospheric parameters, including chemical composition and dynamic properties such as wind velocities and wave motions. Theoretical programs in atmospheric dynamics and transport support the observation programs. An experimental laboratory chemical kinetics program supports the theoretical photochemical modeling program and also supplies input for the development of new atmospheric monitoring and measurement technology.

AOML Atlantic Oceanographic and Meteorological Laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
4301 Rickenbacker Causeway, Virginia Key
Miami, FL 33149
(305) 361-4300, FTS 350-1300

The Atlantic Oceanographic and Meteorological Laboratory conducts research in oceanography and tropical meteorology. It conducts oceanographic investigations centering on fluxes of energy, momentum, and materials through the air-sea interface, the transport and composition (thermal and chemical) of ocean and coastal water masses, and the structure and dynamical processes on the seafloor. It also conducts meteorological research to improve the description, understanding, and prediction of hurricanes. The research supports NOAA's missions in climate, weather, and ocean services, marine environmental assessment, and marine resources.

ARL Air Resources Laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
Silver Spring Metro Center-2, Room 9358
1325 East-West Highway
Silver Spring, MD 20910
(301) 427-7684, FTS 427-7684

The Air Resources Laboratory carries out programs of research that affect air pollution and air quality. These processes are related to transport and dispersion through the air, to reactions with other chemical species, and to exchange between the air and the surface (including both wet and dry deposition). Research on atmospheric trajectories is conducted to relate pollution events to specific causes and to help formulate transport mechanisms in Eulerian and Lagrangian models. The Laboratory manages and coordinates field research and applications to specific research problems. It undertakes research and provides consultation service and advice to elements of NOAA and other government agencies.

AWS Agricultural Weather Section
NOAA/USDA Joint Agricultural Weather Facility
USDA South Bldg., Room 5844
14th Street and Independence Avenue, SW
Washington, DC 20250
(202) 447-7919

The Agricultural Weather Section serves as the NOAA component of the Joint Agricultural Weather Facility at the U.S. Department of Agriculture, Washington, DC. The Section provides an advisory and information service on weather and climate for use by Department of Agriculture officials in assessing impacts of weather and climate on agricultural production throughout the world. It also produces the meteorological and climatic summaries for the jointly published "Weekly Weather and Crop Bulletin."

CAC Climate Analysis Center
National Meteorological Center
NOAA National Weather Service
World Weather Building, Room 606
5200 Auth Rd.
Camp Springs, MD 20233
(301) 763-8167, FTS 763-8167

The Climate Analysis Center prepares monthly and seasonal (90-day) meteorological outlooks; collects and analyzes data to depict current anomalies of climate; researches and develops predictive techniques to improve and extend the present outlooks, both in range and domain; performs diagnostic studies of large-scale climate anomalies; and conducts a program of stratospheric research.

CGS Coast and Geodetic Survey
NOAA National Ocean Service
Washington Science Center-1, Room 1006
6001 Executive Blvd.
Rockville, MD 20852
(301) 443-8204, FTS 443-8204

The Coast and Geodetic Survey plans and directs programs to produce charts and related information for safe navigation of the nation's waterways, territorial seas, and the national airspace. It establishes and maintains the horizontal, vertical, and gravimetric components of the National Geodetic Reference System. The office is responsible for assuring coordinated planning and execution of surveying, charting, and related geophysical data collections to meet national goals. In fulfillment of these objectives, the office conducts geodetic, gravimetric, hydrographic, coastal mapping, and related geophysical surveys; and analyses, compiles, reproduces, and distributes nautical and aeronautical charts and geodetic and other related geophysical data. It conducts research and development to improve surveying and cartographic methods, instruments, equipment, data analysis, and national reference system datums.

CMBAD Coastal Monitoring and Bioeffects Assessment Division
Office of Ocean Resources Conservation and Assessment
NOAA National Ocean Service
Washington Science Center-1, Room 323
6001 Executive Blvd.
Rockville, MD 20852
(301) 443-8933, FTS 443-8933

The Coastal Monitoring and Bioeffects Assessment Division conducts a national program of measurements of toxic compounds in shellfish, bottomfish, and sediments at selected estuarine and coastal locations to determine the status and trends of the levels of these indicators of environmental quality; coordinates a NOAA-wide program of quality assurance for environmental quality measurements to determine and evaluate confidence levels and enhance inter-regional comparability among data sets; and conducts a program of applied research to assess the consequences to populations of valuable living marine resources and human health of contaminants in marine and estuarine environments.

CMDL Climate Monitoring and Diagnostics laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
325 Broadway St.
Boulder, CO 80303
(303) 497-6074, FTS 320-6074

The Climate Monitoring and Diagnostics Laboratory plans and conducts observational and monitoring programs and research necessary to measure and predict climate fluctuations and trends on all time scales. The Laboratory analyzes atmospheric and oceanic data to determine relationships, budgets, sources, sinks, and trends; and applies this information to develop real-time climate indices, predictive techniques, and evaluations of predictions.

COAP Center for Ocean Analysis and Prediction
Office of Ocean and Earth Sciences
Marine Analysis and Interpretation Division
NOAA National Ocean Service
2560 Garden Rd.
Monterey, CA 93940
(408) 467-4241

The Center for Ocean Analysis and Prediction, colocated with the U.S. Navy's Fleet Numerical Oceanography Center, is responsible for the development, exchange, integration, and dissemination to government, industry, and academia of biological, chemical, and physical oceanographic products and services. It supports government, industry, and academic institutions responsible for effective management of the nation's living marine resources. The Center's particular focus is to develop and disseminate a unique series of environmental and living marine resource analyses, forecasts, and assessments that describe and predict the condition and variability of biological, chemical, and physical oceanic phenomena as well as the processes affecting them. It also provides and facilitates easy access to existing information produced by other parts of NOAA or federal/state/academic institutions concerning living marine resources, habitat, coastal zone management, offshore dumping and pollution, and ocean climate processes.

ECD Environmental Conservation Division
Northwest Fisheries Science Center
NOAA National Marine Fisheries Service
2725 Montlake Blvd. E.
Seattle, WA 98112
(206) 553-7737, FTS 399-7737

The Environmental Conservation Division conducts research to determine the impact of environmental changes and effects of contaminants on life processes of marine and anadromous organisms and their habitats in the northwestern United States. Research results are used to analyze potential effects from environmental changes on living marine resources. A major goal is to provide data on the physiological, biochemical, and biological effects of contaminants so that recommendations for protection of aquatic resources can be made.

FSD Fisheries Statistics Division
Office of Research and Environmental Information
NOAA National Marine Fisheries Service
Silver Spring Metro Center-1, Room 8313
1335 East-West Highway
Silver Spring, MD 20910
(301) 427-2328, FTS 427-2328

The Fisheries Statistics Division serves as the principal source of national fishery statistics. The Division provides authoritative advice and guidance on matters related to the collection of statistics (biological, economic, market, and sociological) on domestic recreational fisheries, and domestic and foreign commercial fisheries. It develops national standards, policies, and operational guidelines for the coordinated collection and publication of basic fishery statistics. The Division coordinates regional commercial statistics surveys and market information programs, and formulates, implements and operates national commercial and recreational statistics surveys. It coordinates with other federal agencies on the collection of statistics and market information from statistical data bases; and publishes the official fishery statistics for the U.S. government.

GFDL Geophysical Fluid Dynamics Laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
P.O. Box 308
Princeton, NJ 08542
(609) 452-6500, FTS 298-6500

The Geophysical Fluid Dynamics Laboratory conducts long-lead-time research to understand those physical processes which govern the behavior of the atmosphere and the oceans as complex fluid systems and which are fundamental to application areas in support of NOAA's missions. The laboratory uses, as a major tool, large-scale high-speed computers to simulate the highly intricate atmospheric and oceanic processes.

GSL Geosciences Laboratory
Office of Ocean and Earth Sciences
NOAA National Ocean Service
Rockwall Building, Room 424
11400 Rockville Pike
Rockville, MD 20852
(301) 443-8858, FTS 443-8858

The Geosciences Laboratory is responsible for conducting research and development activities to improve the methods of collecting and disseminating geodetic data. The Laboratory provides leadership at the federal level to develop specifications, standards, and instrumentation for geodetic surveys. It specializes in satellite geodesy and oceanography, and the geodetic aspects of climate and global change.

HRL Hydrologic Research Laboratory
Office of Hydrology
NOAA National Weather Service
Silver Spring Metro Center-2, Room 8348
1325 East-West Highway
Silver Spring, MD 20910
(301) 427-7619, FTS 427-7619

The Hydrologic Research Laboratory supports the National Weather Service hydrologic service program by conducting studies, investigations, and analyses leading to application of new knowledge and new technologies to hydrologic forecasting and related water resources problems. The Laboratory sponsors and conducts applied research for a better understanding of the physical processes and phenomena involved in all phases of the hydrologic cycle. It provides research and development for hydrology-related components of major NWS projects and training and support for the hydrologic services program. It represents NOAA on interagency and international hydrologic research activities.

JIC Navy/NOAA Joint Ice Center
Office of Ocean and Earth Sciences
NOAA National Ocean Service
Federal Building 4, Room 2301
Suitland and Silver Hill Roads
Suitland, MD 20233
(301) 763-5972, FTS 763-5972

The Navy/NOAA Joint Ice Center is composed of both Navy and NOAA personnel. The Center provides specialized and tailored products as required by Department of Defense and other government agencies and provides ice data, analyses, predictions, and other advisory information as guidance to NOAA field forecast offices with sea/lake ice responsibilities. It also provides routine ice products to civil-sector interests.

NCDC National Climatic Data Center
NOAA National Environmental Satellite, Data,
and Information Service
Federal Building
Asheville, NC 28801
(704) 259-0476, FTS 672-0476 (Requests for data:
weather/climate data -0682; satellite data 301/763-8111)

The National Climatic Data Center (NCDC) is responsible for data management activities in support of scientific and technical programs involving remotely sensed and <u>in situ</u> retrospective meteorological data and climatological information. NCDC performs all functions related to data management (acquisition, archiving, inventorying, and quality assessments, modelling, and prediction), and data and information publication and dissemination. It performs necessary liaison with other NOAA components and with national and international contributors and users of data and information. NCDC operates World Data Center-A for Meteorology under the auspices of the National Academy of Sciences, with the responsibility to collect complete sets of global data and coordinate international exchange of data. It performs quality assurance and re-analysis of historical data and data fields to establish baseline data bases for global/national climate monitoring. NCDC provides facilities, data processing support, and expertise to meet U.S. commitments to international organizations and to the World Meteorological Organization programs.

NEFC Northeast Fisheries Science Center
NOAA National Marine Fisheries Service
166 Water St.
Woods Hole, MA 02543
(617) 548-5123, FTS 840-1284

The Science and Research Director, Northeast Region, and the staff of the Northeast Fisheries Science Center are responsible for conducting integrated multidisciplinary research programs to develop scientific information for the conservation and management of living marine resources in the northeast and middle-Atlantic waters of the United States. The staff contributes expertise to the development of fishery management plans by assessing the stocks, their ecosystem relationships, and the total harvestable biomass, and by assessing relevant natural and human-induced ecological environmental effects. The staff conducts fishery utilization technology and development studies to enhance benefits from fishery resources and assure the consumer safe and high quality fishery products. The research to support the programs is conducted at six facilities located at Gloucester, MA; Milford, CT; Narragansett, RI; Oxford, MD; Sandy Hook, NJ; and Woods Hole, MA; and at the National Systematics Laboratory located in Washington, DC.

NGDC National Geophysical Data Center
NOAA National Environmental Satellite, Data, and Information Service
325 Broadway St.
Boulder, CO 80303
(303) 497-6215, FTS 320-6215

The National Geophysical Data Center conducts a data and data-information service in all scientific and technical areas involving solid earth geophysics, marine geology, and geophysics, glaciology (snow and ice), the space environment, solar activity, and the other areas of solar-terrestrial physics. The scientific specialties treated include seismology, geomagnetism, topography, bathymetry, paleoclimatology, gravimetry, earth tides, crustal movement, geothermics, glaciology, ionospheric phenomena, solar activity and related areas. The services are provided for scientific, technical, and lay users in governmental agencies, universities, and the private sector in the U.S. and their counterparts in foreign countries. The Center prepares systematic and special data products and performs data-related research studies to enhance the utility of the service to users. It performs all functions related to data acquisition, archiving, retrieval, indexing, quality assessments, evaluation, synthesis, publication and dissemination. The Center operates World Data Center-A for the respective scientific areas listed above under the auspices of the National Academy of Sciences. It performs necessary liaison about data with other NOAA components and with national and foreign contributors and data centers and other users of data and metadata. It takes part in jointly planning national and international scientific programs to assure that data collection and management needs are adequately considered.

NHC National Hurricane Center
NOAA National Weather Service
IRE Building, Room 631
1320 S. Dixie Highway
Coral Gables, FL 33146
(305) 666-4612, FTS 350-5547

The National Hurricane Center maintains a continuous watch for tropical cyclones over the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico from June 1 through November 30. The Center prepares and distributes hurricane watches and warnings for the general public, and prepares and distributes marine and military advisories for other users. It coordinates with Hurricane Warning Offices, Weather Service Forecast Offices, and Weather Service Offices when a tropical cyclone threatens the U.S. The Center prepares and distributes probability of hurricane/tropical storm conditions for 45 locations along the east and Gulf coasts. It coordinates and occasionally assists Caribbean nations when a hurricane threatens. The Center conducts research and development aimed at general improvements in tropical cyclone forecasting and modelling and concentrates on transfer of theoretical advances to operational forecasting. Related effects of hurricanes, such as high seas and storm surges, are studied.

NMC National Meteorological Center
NOAA National Weather Service
World Weather Building, Room 101
5200 Auth Rd.
Camp Springs, MD 20233
(301) 763-8016, FTS 763-8016

The National Meteorological Center determines input data requirements, optimum data processing and handling techniques, and suitable presentation methods for distributing products to a wide variety of users of meteorological and oceanographic information throughout the Northern Hemisphere. The Center produces and distributes these products to field forecast offices of the National Weather Service, Air Force, Federal Aviation Administration, and other governmental and non-governmental offices. It produces and distributes to foreign meteorological centers products necessary for the discharge of its responsibilities as part of the World Weather Center (Washington, DC). NMC produces extended and medium-range forecasts and develops methods and techniques for their improvement; analyzes, diagnoses, and projects short-term climate fluctuations on a regional and global basis; maintains a continuous weather watch for thunderstorm activity and prepares and disseminates severe local storm watches for protection of life and property; produces and distributes national weather summaries for the general public and advisories of hazardous weather for aviation interests; provides satellite interpretation services and develops and produces oceanographic products; and performs research and development to improve its meteorological, oceanographic, and climate products. The Center maintains a continuous watch for tropical cyclones over the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico; produces and distributes hurricane watches and warnings for the general public, and marine and military hurricane advisories for other users.

NMML National Marine Mammal Laboratory
Alaska Fisheries Science Center
NOAA National Marine Fisheries Service
7600 Sand Point Way, N.E.
BIN C15700 - Bldg. 4
Seattle, WA 98115-0070
(206) 526-4045, FTS 392-4045

The National Marine Mammal Laboratory carries out research on the principal species of marine mammals of U.S. concern to ensure maintenance of the various populations at satisfactory levels. The information obtained is used by national and international agencies as a basis for management decisions concerning marine mammals.

NODC National Oceanographic Data Center
NOAA National Environmental Satellite, Data,
and Information Service
Universal Building, S., Room 406
1825 Connecticut Ave., N.W.
Washington, DC 20235
(202) 673-5549, FTS 673-5549

The National Oceanographic Data Center develops and maintains a national marine environmental data base, including acquisition, processing, storage, and retrieval of marine data and information generated by domestic and foreign activities. The Center provides products and information derived from these data to the federal, state, academic, and internal marine science community. It manages and operates the World Data Center-A for Oceanography. It maintains liaison with federal, state, academic, and industrial oceanographic activities. It represents NOAA on various domestic panels, committees and councils, and represents the U.S. in various international organizations as delegated. The Center represents NOAA to the general public, government agencies, private institutions, foreign governments, and the private sector on matters involving oceanographic data and provides data management services for various marine programs. The Center also manages the Ocean Pollution Data and Information Network.

NSIDC National Snow and Ice Data Center
National Geophysical Data Center
NOAA National Environmental Satellite, Data,
and Information Service
325 Broadway St.
Boulder, CO 80303
(303) 492-5171, FTS 320-5311

The National Snow and Ice Data Center functions as a national information and referral center for the snow and ice research community. The subject matter includes avalanches, freshwater ice, glaciers, ground ice and permafrost, ice sheets, paleoglaciology, sea ice, and snow cover. The Center is colocated with the World Data Center-A for Glaciology (Snow and Ice) and is operated by contractual agreement between NOAA and the University of Colorado, Cooperative Institute for Research in Environmental Sciences. The Center is organizationally located within the National Geophysical Data Center.

NSSL National Severe Storms Laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
1313 Halley Circle
Norman, OK 73069
(405) 366-0429, FTS 736-3427

The National Severe Storms Laboratory examines multiscale processes with emphasis on severe storm developments and interactions to gain improved weather services through increased understanding of environmental processes. Objectives are improved severe weather detection and accuracy of storm forecasts, more timely delivery of critical weather warnings; and better strategies for diminishing loss of life, mitigating property damage, and conserving soil and water resources. Focus is placed on tornadoes and other severe wind storms, hail, lighting, and flash floods. The Laboratory performs related research for other components of NOAA and for other government agencies.

NWFC Northwest Fisheries Science Center
NOAA National Marine Fisheries Service
2725 Montlake Blvd. E.
Seattle, WA 98112-2097
(206) 553-1872, FTS 399-1872

The Science and Research Director, Northwest Region, and the staff of the Northwest Fisheries Science Center are responsible for conducting multidisciplinary research to provide fisheries management information to support national and regional programs of NMFS, and to respond to the needs of Regional Fishery Management Councils and other constituencies. The staff develops the scientific base required for status of stocks and status of fisheries reports, environmental assessment and environmental impact statements for management plans and/or international negotiations; and it pursues research to answer specific needs in the subject areas of habitat conservation, aquaculture, fishery engineering, marine mammals, endangered species, fishery development, fishery oceanography, food science, fishery economics, and fishery utilization.

OLLD Ocean and Lake Levels Division
Office of Ocean and Earth Sciences
NOAA National Ocean Service
Washington Science Center-1, Room 110
6001 Executive Blvd.
Rockville, MD 20852
(301) 443-8026, FTS 443-8026

The Ocean and Lake Levels Division provides tide and water level (Great Lakes) information. The Division investigates and studies tide and water level phenomena and related surface water temperatures and density through recorded observations; provides direction for the collection of tide and water level data and determination of tidal datums through the preparation of manuals, guides, contract documents, and project instructions; and processes, analyzes, compiles, and disseminates tide, water level, and surface water and density information from domestic sources. It manages the National Water Level Observation Network, the Next-Generation Water Level Measurement System Program, and the Global Absolute Sea-Level Monitoring Program. The Division plans tidal surveys; furnishes tide and water level information for planning and processing hydrographic surveys; and makes various studies and prepares reports related to gaging systems, methodology, analysis techniques, tidal datums, the Great Lakes datum, the outflow of rivers, and related subjects.

OPC Ocean Products Center
Office of Ocean and Earth Sciences
NOAA National Ocean Service
World Weather Building, Room 100
5200 Auth Rd.
Camp Springs, MD 20233
(301) 763-8030, FTS 763-8030

The Ocean Products Division conducts a program to provide operational marine forecast and analysis guidance material in support of NOAA, other federal agencies, and private industry. To this end, it participates in the formulation of requirements for data processing and communications equipment to process and distribute marine meteorological and oceanographic data and products, and designs and manages computer-based systems in support of these requirements. It participates in the establishment of requirements for marine data sets, develops operational state-of-the-art numerical-prediction-model output products, and improves methods of data analysis. Output products include analyses of marine weather and boundary layer phenomena, waves and wave dynamics, ocean thermal structure and dynamics, ice dynamics, and estuarine circulation and coastal processes.

OPR Office of Protected Resources
NOAA National Marine Fisheries Service
Silver Spring Metro Center-1
1335 East-West Highway, Room 8268
Silver Spring, MD 20910
(301) 427-2332, FTS 427-2332

The Office of Protected Resources provides advice and guidance on the conservation and protection of those marine mammals and endangered species under the jurisdiction of the Secretary of Commerce, and on the conservation, restoration, and enhancement of living marine resources and their habitats; develops national guidelines and policies for relevant research programs; and provides oversight, advice and guidance on scientific aspects of managing protected species, marine protected areas and habitat.

PFEG Pacific Fisheries Environmental Group
Southwest Fisheries Science Center
NOAA National Marine Fisheries Service
P.O. Box 831
Monterey, CA 93942
(408) 646-3311, FTS 646-3311

The Pacific Fisheries Environmental Group conducts marine environmental studies, provides portrayals and interpretations of oceanographic and meteorological data, and investigates interrelations for use in fisheries and environmental forecasting. Based on these studies and activities, the Group provides assistance in the development of marine environmental monitoring programs; utilizes and provides archived oceanic and atmospheric data for climatological and monitoring studies; and develops long-term ocean forecasting techniques, models, and indices. It assists NMFS laboratories in the design and conduct of oceanographic studies, and the acquisition of environmental data and interpretation of bio-environmental relationships.

PMEL Pacific Marine Environmental Laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
Bin C 15700, Bldg. 3
7600 Sand Point Way, N.E.
Seattle, WA 98115-0070
(206) 526-6239, FTS 392-6800

The Pacific Marine Environmental Research Laboratory conducts research in oceanography, marine meteorology, and related disciplines to improve understanding of environmental processes in coastal and open-ocean systems. It focuses on NOAA's missions in climate, ocean services, marine environmental assessment, and marine resources.

RCCs Regional Climate Centers:

Northeast Regional
Climate Center
1113 Bradfield Hall
Cornell University
Ithaca, NY 14853
(607) 255-5950

Southern Regional
Climate Center
Department of Geography
and Anthropology
Louisiana State University
Baton Rouge, LA 70803
(504) 388-6870/6184

High Plains Regional
Climate Center
237 L.W. Chase Hall
University of Nebraska-Lincoln
Lincoln, NE 68583-0728
(402) 472-6338

Southeastern Regional
Climate Center
1201 N. Main Street
Capital Center, Suite 1100
Columbia, SC 29201
(803) 737-0800/0811

Midwestern Regional
Climate Center
Ill. State Water Survey
2204 Griffith Dr.
Champaign, IL 61820
(217) 244-1488

Western Regional
Climate Center
Desert Research Institute
P.O. Box 60220
Reno, NV 89506-0220
(702) 677-3100

A national network of six Regional Climate Centers (RCCs) was established by the National Climate Program Act of 1978. The Centers are a federal-state cooperative program with oversight provided by the Climate Analysis Center/NOAA National Weather Service. The RCCs are a source of climate expertise; perform data management services and specialized product delivery; conduct applied climate studies, monitoring and regional research; and acquire and maintain specialized regional data sets.

SAL Satellite Applications Laboratory
Office of Research and Applications
NOAA National Environmental Satellite, Data,
and Information Service
World Weather Building, Room 601
5200 Auth Rd.
Camp Springs, MD 20233
(301) 763-8282, FTS 763-8282

The Satellite Applications Laboratory provides an interface to the research community to ensure that research results are carried smoothly into operational use. The Laboratory develops and specifies new products, services, and techniques; develops test and pilot operations; trains operational users of the products; and turns over systems or components for operational use. It conducts training and consultation in the application of environmental satellite data and research into the feasibility of obtaining atmospheric variables and files with high spatial and temporal resolution from satellite measurements for various meteorological applications. The Laboratory develops satellite data and products that are useful for agricultural resource inventory and monitoring, develops and evaluates new techniques in remote-sensing technology, and serves as a focal point for measurements of stratospheric trace constituents for climate and environmental purposes.

SDSD Satellite Data Services Division
National Climatic Data Center
NOAA National Environmental Satellite, Data, and Information Service
Princeton Executive Center, Room 100
5627 Allentown Rd.
Washington, DC 20233
(301) 763-8402, FTS 763-8402

The Satellite Data Services Division receives, classifies, stores, and retrieves imagery and digital data from environmental satellites. The Division is responsible for planning, systems analysis design, and coordination involved in acquiring new or improving current systems required to perform the satellite data management and user services functions. It performs feasibility studies and develops specifications for satellite data handling, hardware/software systems, and automatic data-processing services. The Division furnishes guidance to researchers and planners in selecting data sources suitable to their needs. It provides professional services in analyzing, interpreting, and filling user requests for retrospective satellite data. In response to inquiries, the Division furnishes data or information as to types of data available in various media and formats.

SEAD Strategic Environmental Assessments Division
Office Ocean Resources Conservation and Assessment
NOAA National Ocean Service
Washington Science Center-1, Room 220
6001 Executive Blvd.
Rockville, MD 20852
(301) 443-8843, FTS 443-8843

The Strategic Environmental Assessment Division conducts comprehensive, interdisciplinary assessments of multiple ocean-resource uses for the nation and its major coastal and oceanic regions for applications by NOAA, other agencies, Congress, and public interest groups in identifying ocean uses capabilities and potential conflicts and determining national research needs and priorities. The Division publishes a series of data atlases of important physical, chemical, biological, and economic characteristics of the nation's coastal zone and Exclusive Economic Zone. It develops and maintains comprehensive, national inventories of coastal and ocean resources and their existing and proposed uses for assessing national policies and management strategies. It also develops strategic assessment methods and maintains an operational capability with which to evaluate the environmental and economic effects of national policies and management strategies for coastal and ocean resource use. The Division synthesizes and disseminates information on the use and status of coastal waters of the nation.

SEFC Southeast Fisheries Science Center
NOAA National Marine Fisheries Service
75 Virginia Beach Dr.
Miami, FL 33149
(305) 361-4284, FTS 350-1284

The Southeast Fisheries Science Center conducts multidisciplinary research programs to provide management information to support national and regional programs of NMFS; and to respond to the needs of regional Fishery Management Councils, interstate and international fishery commissions, fishery development foundations, government agencies, and the general public. The Center provides supervisory and administrative support to large marine ecosystems programs performing fishery research, collecting and reporting on statistical data, and operating Center data management support systems. It develops the scientific information base required for fishery resource conservation, fishery development and utilization, habitat conservation, and protection of marine mammals and endangered species; develops the impact analyses and environmental assessments for management plans and/or international negotiations; and pursues research to answer specific needs in the subject areas of population dynamics, fishery biology, fishery economics, fishery engineering, food science, and fishery biology.

SEL Space Environment Laboratory
Environmental Research Laboratories
NOAA Office of Oceanic and Atmospheric Research
325 Broadway St.
Boulder, CO 80303
(303) 497-3311, FTS 320-3311

The Space Environment Laboratory provides monitoring and forecasting of the space environment to meet national requirements. The Laboratory improves techniques for forecasting solar disturbances and their effects on the Earth's environment through research and technical support activities.

SRD Sanctuaries and Reserves Division
Office of Ocean and Coastal Resources Management
NOAA National Ocean Service
Universal Building S., Room 714
1825 Connecticut Ave., NW
Washington, DC, 20235
(201) 673-5122, FTS 673-5122

The Sanctuaries and Reserves Division has headquarters and field staff responsible for administration of the National Marine Sanctuary Program, Title III of the Marine Protection, Research, and Sanctuaries Act, and the National Estuarine Reserve Research System, section 315 of the Coastal Zone Management Act. These programs identify, designate, and operate coastal marine protected areas for purposes of resource protection, monitoring, research, interpretation, and education. The Division prepares necessary designation documents for these sites including management plans, regulations, environmental impact statements, Congressional prospectuses, and designation findings. It oversees state operation of reserves and directly operates marine sanctuaries, including the issuance and monitoring of permits to conduct specified activities and enforcement of sanctuary regulations. The Division develops and implements national interpretative, educational, research, monitoring, and cultural resource plans and site-specific management plans and projects.

SRL Satellite Research Laboratory
Office of Research and Applications
NOAA National Environmental Satellite, Data, and Information Service
World Weather Building, Room 712
5200 Auth Rd.
Camp Springs, MD 20233
(301) 763-8078, FTS 763-8078

The Satellite Research Laboratory applies satellite observations to solving problems in the atmospheric, oceanic, and land sciences and in climate research and monitoring. The Laboratory develops methods for remote sensing of the Earth and its atmosphere. The Laboratory performs research using satellite observations; supports such research activities at university and private research organizations; and participates with the university community in joint research projects. It plans and coordinates research and development activities and applications of research results with other parts of NOAA and other U.S. government agencies, universities, and international groups. The Laboratory conducts field experiments to demonstrate the utility of new measurement techniques, new results, and new technology. Areas of experimentation include atmospheric, oceanographic, hydrologic, and Earth resources investigations.

SSD Satellite Services Division
Office of Satellite Data Processing and Distribution
NOAA National Environmental Satellite, Data, and Information Service
World Weather Building, Room 607
5200 Auth Rd.
Camp Springs, MD 20233
(301) 763-8051, FTS 763-8051

The Satellite Services Division serves as the primary interface with the community of users of environmental satellite data and products. The Division is responsible for providing data, analyses, and interpretations of polar-orbiting and geostationary satellite data to the user community. It also serves as the primary interface with the users of satellite direct-broadcast and data-collection services, and manages the operation and maintenance of the Geostationary Operational Environmental Satellite Data Collection System.

SWFC Southwest Fisheries Science Center
NOAA National Marine Fisheries Service
P.O. Box 271
La Jolla, CA 92038
(619) 546-7000, FTS 893-7000

The Science and Research Director, Southwest Region, and the staff of the Southwest Fisheries Science Center are responsible for conducting an integrated, multidisciplinary research program in biology, mathematics, oceanography, economics, and computer sciences for the purpose of developing scientific information to support the management and allocation of coastal and high-seas fishery resources. These activities are designed to support the scientific, statistical, and economic needs of the regional Fishery Management Councils, international commissions for the allocation of world-wide tuna resources, efforts directed toward the reduction of porpoise mortality, a better understanding of the biological and environmental factors affecting commercial and recreational fisheries, and the development of underutilized fishery resources.

APPENDIX C: GLOSSARY OF TERMS

aerosol -- Suspension of very small particles of a liquid or a solid in air or another gas. Examples include smoke, dust, and fog.

albedo -- The fraction of incident light reflected from a surface.

biosphere -- The portion of the Earth inhabited by living organisms, including the land masses, oceans, and atmosphere.

bycatch -- Catch of nontarget fish and invertebrates during commercial fishing operations, especially trawling. For example, commercial shrimp fishing results in an extensive bycatch of bottomfish species, most of which are killed and discarded.

chlorofluorocarbons -- Group of organic compounds analogous to hydrocarbons, in which all or most of the hydrogen atoms of a hydrocarbon have been replaced by fluorine or chlorine; see halogens.

condensation nuclei -- Aerosol which serve as the nuclei upon which water vapor condenses. Cloud condensation nuclei occur in the atmosphere.

DDT -- A persistent insecticide which is a mixture of isomers of dichlorodiphenyltrichloroethane, a chlorinated hydrocarbon.

DNA -- Deoxyribonucleic acid; the primary genetic material of a cell; contains 2 polynucleotide chains forming a double helix.

Dobson unit -- Unit of measurement of ozone concentration in atmosphere. Represents the amount of ozone in a vertical column of the atmosphere at standard temperature and atmospheric pressure. 1 Dobson unit = 10^{-3} cm of ozone at standard temperature and atmospheric pressure. Named after G.M.B. Dobson, English inventor of ozone spectrophotometer and first to establish a routine ozone-observing program in 1924.

dogfish -- One of several species of small sharks of the genera Squalus and Mustelus.

EEZ -- See Exclusive Economic Zone.

electromagnetic sensing -- Remote sensing of ocean transport using naturally occurring electric currents caused by flow through the Earth's magnetic field. Measurements of induced electric fields and resulting currents are made from submarine cables, towed electrode systems, and free-fall profilers.

El Nino -- Anomalous warming of the eastern tropical Pacific Ocean that occurs at 2-10 year intervals and is frequently associated with far-reaching climatic and economic impacts around the world.

ENSO -- El Nino (q.v.)/Southern Oscillation (q.v.) (ENSO) -- term used to describe the oceanic-atmospheric interactions of El Nino events.

ERL -- The Environmental Research Laboratories (ERL) are organized within NOAA's OAR (q.v.). ERL consists of 10 research laboratories and 7 joint/cooperative research institutes throughout the U.S.

Exclusive Economic Zone -- Coastal ocean under limited U.S. legal jurisdiction. By law, the Exclusive Economic Zone (EEZ) is defined as contiguous to the territorial sea of the U.S. and extending seaward 200 nautical miles measured from the baseline from which the territorial sea was measured. Under the Magnuson Fishery Conservation and Management Act, the U.S. has exclusive management authority over all living marine resources in the EEZ.

Florida Current -- A north Atlantic Ocean western boundary current (q.v.) setting northward along the southeast coast of the United States. A segment of the Gulf Stream system, the Florida Current extends from the Straits of Florida to the region off Cape Hatteras, NC. Part of the general surface circulation of the oceans.

gadoids -- Family of fishes (Gadidae) which includes several important genera widely used as food, such as cod, haddock, pollock, and hake.

gag -- The grouper of southern U.S. coasts, West Indies, and Caribbean waters. Groupers are large marine fish of the family Serranidae common in warm waters, especially around reefs. It is a popular sport fish and excellent food fish. The common name for the grouper, <u>Mycteroperca microlepis</u>.

GEOSAT -- GEOdetic SATellite. U.S. Navy altimeter satellite launched in 1985 used to collect global altimeter data.

GOES -- New NOAA system of Geostationary Operational Environmental Satellites (GOES).

greenhouse effect -- Theory associated with increase in "greenhouse gases" (e.g., carbon dioxide, methane, nitrous oxide, tropospheric ozone, chlorofluorocarbons) and their ability to absorb thermal infrared radiation which increases atmospheric

temperatures.
halogens -- The five elements fluorine, chlorine, bromine, iodine, and astatine. Organic compounds formed from these include chlorofluorocarbons, chlorinated hydrocarbons, and various plastics.

infrared radiation -- Long-wave (heat) radiation (abbreviation: IR) emitted by hot bodies with wavelengths ranging from the limit of the red end of the visible spectrum to about 1 mm.

IR -- see infrared radiation.

joint venture -- An operation authorized under the Magnuson Fishery Conservation and Management Act in which a permitted foreign vessel receives fish in the U.S. Exclusive Economic Zone from a U.S. vessel. The fish received from the U.S. vessel are part of the U.S. harvest.

La Nina -- Periods between El Nino events in the eastern tropical Pacific characterized by normal ocean/atmospheric conditions (i.e. a "cool" event).

longline fishery -- Method of fishing using long lines of baited hooks. Hooks used are small and spaced at short intervals. Usually 1/4 to 2 miles long. Commonly used for catching a variety of fish, including sharks, snappers, groupers, and tuna.

Magnuson Fishery Conservation and Management Act -- The Magnuson Act provides a national program for the conservation and management of fisheries to allow for optimum yield on a continuing basis. It established the U.S. Exclusive Economic Zone and a means to control foreign and certain domestic fisheries through fishery management plans.

mb -- see millibar.

methane -- The simplest hydrocarbon, found in natural gas and as a degradation product of carbonaceous materials, and thus occurs in association with petroleum, coal, bogs, and marshes. The second most-abundant greenhouse gas, after carbon dioxide.

MFCMA -- see Magnuson Fishery Conservation and Management Act

microgram -- One-millionth (10^{-6}) of a gram.

micrometer -- see micron.

micron -- A unit of measurement (symbol:u) in the metric system equivalent to one-millionth meter (10^{-6} meter). Also called a micrometer.

microwaves -- Portion of electromagnetic spectrum lying between the far infrared and radio frequencies, i.e., wavelengths from 1 to 1000 millimeters.

millibar -- Commonly used unit of pressure (symbol: mb) in meteorology (1 mb = 10^3 dynes/cm^2). 1013 mb is regarded as the standard atmospheric pressure at sea level.

mitigation -- Actions taken to reduce the effects of a potentially harmful activity.

mixing ratio -- Ratio of the mass of a given gas (e.g., water vapor) to that of the remaining gas (e.g., dry air) in the mixture.

nanogram -- One-billionth of a gram. The prefix nano (symbol: n) means one-billionth part (10^{-9}).

NESDIS -- National Environmental Satellite, Data, and Information Service (NESDIS). Office responsible for NOAA's environmental satellite and data management programs.

nitrous oxide -- A greenhouse gas (N_2O) of primarily biogenic origin. N_2O absorbs in the thermal infrared spectrum and contributes to warming of the atmosphere.

Nimbus-7 -- Satellite used to fly the Coastal Zone Color Scanner (CZCS) and Total Ozone Mapping Spectrophotometer (q.v.).

NMFS -- National Marine Fisheries Service. Office responsible for the integrated NOAA marine fisheries programs.

NOS -- National Ocean Service. Office responsible for the integrated NOAA ocean services and coastal zone management programs.

NWS -- National Weather Service. Office responsible for the integrated NOAA weather service programs.

orographic -- Applied to rain or clouds caused by the condensation of moist air resulting from the forced uplift of mountains on air streams that cross them.

OAR -- Office of Oceanic and Atmospheric Research. Office responsible for the integrated NOAA oceanic and atmospheric research and development programs.

ozone -- Photochemically produced form of oxygen (symbol: O_3). Ozone shields the Earth from solar ultraviolet radiation and acts as a strong oxidizing agent for chemical reactions involving other biogenic gases.

PAHs -- Polyaromatic hydrocarbons are cyclic (closed rings typified by benzene-C_6H_6) hydrocarbons derived mainly from petroleum. Includes naphthalene, fluorene, pyrene, and benzo(a)pyrene.

Palmer Drought Severity Index -- Index of dryness (drought) developed by Wayne C. Palmer of the NWS to quantify negative meteorological moisture anomalies.

PCBs -- Polychlorinated biphenyls are chlorinated hydrocarbon compounds first used in 1929 for industrial purposes and occur as persistent pollutants, particularly in aquatic ecosystems. Their use in the U.S. began to be phased out in 1971 and has been banned in new devices since 1976.

pixel -- A picture element. Commonly the smallest component of a multispectral image.

polynyas -- A water area enclosed in ice.

precipitation index -- Statistically derived index that depicts average precipitation (moisture) over long time periods and large geographic areas.

QBO -- see quasi-biennial oscillation.

quasi-biennial oscillation -- Equatorial east-west oscillation of stratospheric winds. The quasi-biennial oscillation (QBO) has a period of about 26 months and has largest amplitude near 30 mb pressure. The QBO shows a strong relationship with Atlantic tropical storm activity.

radiosonde -- Meteorological instrument that records and transmits atmospheric temperatures and humidity with altitude. CIt is carried aloft by balloon.

rawinsonde -- Meteorological instrument that records and transmits atmospheric temperatures and wind direction/speed with altitude. It is usually carried aloft by balloon.

rocketsonde -- Radiosonde (q.v.) or rawinsonde (q.v.) carried aloft by rocket.

Sahel -- Geographical area in north central Africa (Mauritania to Chad) between the Sahara desert of North Africa and the forested regions of equatorial Africa. This region is arid with sparse vegetation and is susceptible to desertification.

sea level -- Level of the ocean surface in relation to adjacent land (secular sea level) or from a satellite at a known altitude (absolute sea level).

SEAMAP -- Southeast Area Monitoring and Assessment Program.

State/federal/university program for collection, management, and dissemination of fishery-independent data and information in the southeastern United States.

shellfish -- Any aquatic invertebrate possessing a shell, especially any edible mollusk or crustacean, as oysters, clams, lobsters, and shrimps.

skates -- Fish of the genus Raja (family Rajidae) related to sharks and rays. Skates are frequently caught as bycatch and discarded.

solar irradiance -- The total solar radiation received on a surface per unit area.

Southern Oscillation -- An intermittent 2-10 year quasi-periodicity observed in atmospheric pressure, surface wind, sea surface temperature, cloudiness, and rainfall over a wide area of the Pacific Ocean and adjacent coastal areas south of the equator.

stratosphere -- The upper portion of Earth's atmosphere, above the troposphere (from 8-20 km) and below the mesosphere (to around 45 km), characterized by relatively uniform temperatures and horizontal winds (jet stream).

sunspot -- Dark areas seen on the Sun's surface that are regions of cool gas. Their presence is associated with local variations in the Sun's magnetic field. Sunspots appear to have cycles having a period of 11 years.

Sverdrup -- Unit of measurement (symbol: SV) used to quantify the ocean volume transported. 1 sverdrup = one million cubic meters per second.

TOGA -- Tropical Ocean and Global Atmosphere Program. Part of the 10-year (1985-1995) international World Climate Research Program established by the World Meteorological Organization. NOAA is an active participant in TOGA.

TOMS -- Total Ozone Mapping Spectrophotometer. Instrument flown aboard Nimbus-7 satellite used to remotely measure stratospheric ozone.

tornado -- Intense, funnel-shaped wind phenomena usually associated with fast-moving cold fronts.

tropical cyclone -- Intense, circular, cyclonic storms formed in ocean regions.

troposphere -- The lowest layer of the Earth's atmosphere extending from the surface to the tropopause (10-20 km depending on latitude and time of year). Temperature decreases steadily with increased altitude, turbulence is greatest, and most weather phenomena occur in this region.

upwelling -- An upward flow of subsurface water due to divergences, offshore winds, and wind-driven transport away from shore.

virtual population analysis -- An analysis of the catches from a given year class (cohort) of fish over its life in the fishery.
visible wavelengths -- The continuous spectrum of visible radiation lying in the wavelength range between 380 and 780 nanometers. Seven colors are usually distinguished in the continuous variation of visible wavelengths: violet, indigo, blue, green, yellow, orange, and red.

western boundary currents -- Currents of the major ocean gyres flowing along the eastern coasts of all continents. These currents are fast, narrow, and, in some regions, meander unpredictably. Examples of these currents are the Kuroshio Current in the Pacific Ocean and the Florida Current (q.v.) and Gulf Stream in the Atlantic Ocean.

wind stress -- Frictional drag at the boundary between the air-sea interface. One of the physical forces influencing ocean circulation.

xenobiotic -- A compound foreign to or not found naturally in the environment. Examples include DDT (q.v.) and PCBs (q.v.).

APPENDIX D: RELATED REPORTS AND PUBLICATIONS

A number of publications, both governmental and private, present regular analyses of the Earth's environment and natural resources. In addition, there are numerous special reports and scientific journals that periodically deal with global environmental issues. Examples of significant publications related to this report are:

Climate Assessment: Selected Indicators of Global Climate -- Published jointly by NOAA's Climate Analysis Center and National Climatic Data Center, this yearly report provides an annual summary (including historical perspectives) of selected atmospheric and oceanic parameters including sea ice and snow cover. Global coverage is emphasized although regional and United States conditions are also highlighted.

Climate Diagnostics Bulletin -- Published by NOAA's Climate Analysis Center, this report is a summary of worldwide monthly meteorological data such as sea surface temperature, sea surface pressure, winds, and ocean currents. Anomalies are noted and discussed.

Environmental Indicators: A Preliminary Set -- A preliminary set of environmental indicators published by the Organization for Economic Cooperation and Development (OECD, Paris 1991). It serves as a companion to the OECD Report on the State of the Environment and comprises 18 environmental indicators, followed by 7 key indicators reflecting economic and population changes of environmental significance.

Environmental Trends -- A publication of the Council on Environmental Quality which focuses on selected U.S. indicators chosen by an Interagency Advisory Committee on Environmental Trends. Statistical series are compiled from data available through government agencies, private studies, or the literature of each discipline. Chapters concern minerals, energy, water, climate, air quality, land resources, wildlife, wetlands, protected areas, population, transportation, and environmental hazards.

Environmental Quality -- The annual report of the Council on Environmental Quality. The report is submitted to Congress and highlights selected environmental issues. These selected topics are discussed in considerable depth. The focus is on the United States. Appendices identify activities of the Council, highlight specific environmental legislation, and provide numerical data intabular form together with the President's Message to Congress.

Fisheries of the United States -- Published yearly by NOAA's National Marine Fisheries Service (NMFS), Fisheries Statistics Division. The publication is a preliminary report giving annual statistics on commercial and recreational fisheries of the United States and foreign catch in the U.S. Exclusive Economic Zone. Final data are published in "Fishery Statistics of the United States" and other NMFS statistical publications. Data are provided on U.S. employment, prices, and production of processed products. Worldwide data are also included.

Geophysical Monitoring for Climatic Change Summary Report -- This is an annual report published by the Geophysical Monitoring for Climatic Change Division of NOAA's Climate Monitoring and Diagnostics Laboratory. The report contains scientific information on a number of geophysical parameters monitored at NOAA's baseline observatories. These parameters include: atmospheric aerosols, solar radiation, atmospheric turbidity, carbon dioxide, ozone, water vapor, and other atmospheric parameters of climatological significance.

GESAMP: The State of the Marine Environment -- This report, prepared by the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) (United Nations Environment Program Regional Seas Reports and Studies No. 115. UNEP, 1990), summarizes the state of marine pollution in the world's oceans and is the second state-of-the-marine-environment report by the Group. Topics include human activities affecting the sea, marine contaminants, biological effects, climate change effects, and prevention and control of marine pollution.

The Global Climate System Monitoring Bulletin -- The report, published bi-annually by the World Meteorological Organization, is a review of global climate conditions based on current scientific understanding and worldwide observations of the climate system. It is intended to provide a basis for monitoring global change. The report is compiled from readily available scientific literature and has an extensive bibliography.

Monthly Climatic Time Series Data for the Pacific Ocean and Western Americas -- Published by the U.S. Geological Survey (USGS Open-File Report 91-92) in cooperation with Scripps Institution of Oceanography, NOAA, and the State of California. Graphs of standardized monthly anomaly time-series data for several climatic variables are presented for locations in the eastern Pacific Ocean and the western Americas. The variables include: air temperature, barometric pressure, precipitation, streamflow, sunshine, sea level height, sea surface temperature, sea surface salinity, several atmospheric indices and biological variables, ocean and miscellaneous ocean subsurface temperature and salinity. The time series of annual values and basic statistics of the monthly mean data are also shown for each variable.

OECD Environmental Data Compendium 1991 -- The third update of the Organization for Economic Co-operation and Development's (OECD, Paris 1991) comprehensive data resource on the environment. Provides data on air and water pollution, the marine environment, land use, forests, wildlife, solid waste, noise, and radioactivity in OECD countries. Also provides data on the underlying anthropogenic pressures on the environment, including energy use, transportation, industrial activity, and agriculture.

Report to Congress on Ocean Pollution, Monitoring, and Research -- This is an annual report published by the Office of Ocean Resources Conservation and Assessment of NOAA's National Ocean Service. The publication details NOAA pollution-related programs including the National Coastal Pollution Discharge Inventory, National Estuarine Inventory, National Status and Trends Program, National Ocean Pollution Program, and special reports on water-quality issues of national significance.

Solar-Geophysical Data -- Published by NOAA's National Geophysical Data Center, the monthly two-part report, is a comprehensive listing of solar flares, solar radio flux, sunspots, solar wind and data on particle measurements, geomagnetic field variations, and cosmic rays.

A State of the Environment Report: A Report on Canada's Progress Towards a National Set of Environmental Indicators -- This report, from Environment Canada (SOE Report No. 91-1, January 1991), documents the current systematic efforts to develop a national set of environmental indicators that, taken together, will give a profile of the state of Canada's environment and indicate trends towards sustainable development.

The State of the Environment, Third Edition -- The latest Organization for Economic Co-operation and Development (OECD, Paris 1991) assessment of environmental conditions in its member countries. It reviews the environment today to assess the progress achieved over the past two decades. It also identifies the remaining problems concerning global atmospheric issues, air, inland waters, the marine environment, land, forest, wildlife, solid waste, and noise. Extensive statistical information is included.

State of the World: A Worldwatch Institute Report on Progress Toward a Sustainable Society -- This is an annual report by Lester Brown et al. of the World Watch Institute. The report discusses global environmental problems that especially affect peoples' lives, including, deforestation, toxic pollution, overpopulation, species extinction, and energy uses. The publication also covers political issues, such as the military buildup in various countries. The report is translated and published in all major languages.

Trends 90: A Compendium of Data on Global Change -- Published by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, the document is a source of frequently-used global-change data. The first issue (August 1990) includes estimates for global and national CO^2 emissions from the burning of fossil fuels and from the production of cement; historical and modern concentrations; and several long-term temperature records. Included are tabular and graphical presentations of the data, discussions of trends in the data, and references to publications that provide further information.

World Resources: A Guide to the Global Environment -- This annual report by the World Resources Institute, Washington, DC, was first published in 1986. The publication reviews global environmental issues such as population and health, food and agriculture, forests and rangelands, atmosphere and climate, oceans and coasts, wildlife and habitats, and global systems. In addition, the report provides quantitative information on issues related to economic indicators, population, public health, land and water use, etc.

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APPENDIX F: NOAA HIGHLIGHTS

The National Oceanic and Atmospheric Administration plays an active role in research, monitoring, and management of national and global environmental events and resources. This section highlights some of the major environmental events since the last NOAA Environmental Digest that have involved the participation of NOAA scientists and resource managers.

Modest Increase Detected in Greenhouse Gases. NOAA's Climate Monitoring and Diagnostics Laboratory in Boulder, CO reported carbon dioxide seems to be increasing faster than in past years, The concentration increased at an average rate of 1.71 ppm/year (0.5%/yr) over the last four years. The rate is higher than the annual 1.5 ppm rise reported for much of the 1980s and the 0.7 ppm increase in the 1960s. Methane concentrations have been rising by about 12 ppb/year (0.8%/yr), and nitrous oxide increased at a rate of 0.7 ppb/year (0.25%/yr). CFC-11 and CFC-12 were reported to be rising at 10 and 16 ppt/year (4%/yr), respectively. The NOAA Laboratory conducts ongoing, long-term monitoring of trace gases from baseline observatories at Barrow, Alaska; Hilo, Hawaii; Pago Pago, American Samoa; and South Pole Station, Antarctica (August 1990).

Northern Hemisphere Snow Cover Lowest Since 1967 During June/July. NOAA's Climate Analysis Center reported that snow cover over the Northern Hemisphere in June and July was the lowest since 1967, when NOAA satellites began recording it. NOAA imagery showed North America at approximately 60 percent of normal June-July cover and less than 40 percent across Europe and Asia, something scientists would expect to occur by chance only once or twice every few hundred years. Snow cover is a critical ingredient in global warming and has major regional effects on water resources, agriculture and local weather. The extremely low snow cover is clearly linked to the record and near-record high-latitude warmth that occurred in the spring and summer. The scientists cautioned that these temperatures may be a reflection of the random nature of snow-cover variations and may have no relationship to climate change associated with global warming (August 1990).

Sea Turtle Strandings Reach Record Numbers. Statistics from the NOAA National Sea Turtle Stranding and Salvage Network show record numbers of sea turtles stranded as of July 1990 in the southeast United States. In 1989, Florida recorded 1,100 turtles washed ashore; Texas had 255 strandings; Georgia had 169; and North Carolina got 156 strandings. All states in the network, except North Carolina, had increased strandings over 1988. The network is composed mostly of volunteers and is managed by NOAA's National Marine Fisheries Service (August 1990).

Endangered Sea Turtles Released in The Gulf of Mexico. Young endangered Kemp's ridley sea turtles numbering 1,850 were released into the Gulf of Mexico as part of an ongoing "headstart" program to increase the population of the turtle. The Kemp's ridleys had been collected as hatchlings at the only known nesting beach in Mexico in July 1990. They were transported to NOAA's National Marine Fisheries Service Laboratory at Galveston, TX, where they were kept prior to release. The turtles released brought to more than 16,000 the number released off Port Aransas, TX, over the last 12 years (August 1990).

Three-Dimensional Maps of the U.S. EEZ Released. The first three-dimensional (3-d) detailed maps of the west coast United States Exclusive Economic Zone (EEZ) were released by NOAA's Nautical Charting Division. NOAA, in cooperation with the U.S. Geological Survey, have been using an advanced, long-range, side-scan sonar imaging system towed behind NOAA ships to map the nation's coastal bottom. NOAA has surveyed only 2 percent, or 80,500 square miles, of the EEZ. The 3-d maps produced thus far include several 2,000-square-mile areas off the coast of California, one off Oregon, and four in the Gulf of Mexico. Maps of six areas near Hawaii are also nearly completed (August 1990).

Monterey Bay National Marine Sanctuary Draft EIS Released. The nation's newest proposed marine sanctuary, Monterey Bay (CA) National Marine Sanctuary, moved closer to reality as NOAA's Sanctuaries and Reserves Division released a draft Environmental Impact Statement (EIS) for public review. The proposed sanctuary could encompass 2,200 square nautical miles, making it the nation's largest. A final EIS will be completed in 1991 (August 1990).

Tampa Bay Oceanography Project Gets Underway. A unique oceanographic study of Tampa Bay (FL) was initiated by NOAA's Ocean Observations Division. A 15-month study will lay the groundwork for a three-dimensional computer model of Tampa Bay's tides, winds, and currents. A real-time reporting system is being developed and tested at the same time. The system, called PORTS (physical oceanographic real-time system), reports real-time oceanographic data to the U. S. Coast Guard Base in St. Petersburg. Harbor pilots, ship captains, and recreational boaters are expected to benefit from the system. Water quality studies, search and rescue operations, and hazardous spill response efforts also could benefit. The system may eventually be installed in additional harbors around the country (August 1990).

NOAA Establishes Undersea Research Center in Alaska. NOAA's National Undersea Research Program set up a new Undersea Research Center at the University of Alaska to support marine research in the U.S. west coast and Alaskan waters. The NOAA/University of

Alaska Center, the fifth in a network of university-based regional National Undersea Research Centers around the country, will provide manned submersibles, remotely-operated underwater vehicles, and facilities to support research (September 1990).

Spring Global Surface Air Temperature Warmest on Record. NOAA's Air Resources Laboratory reported that the average global surface temperature for spring 1990 was the warmest on record (averaging more than 1.5°F above the 30-year average of 54°F and a half degree warmer than the previous record year). The greatest temperature rise was in the Arctic where the average was about 7.2° above average and 4.5°F higher than previously observed. Scientist cautioned that this analysis should not be construed that global warming is occurring (October 1990).

Coral Bleaching Analyzed by NOAA Researchers. The recurring phenomena of coral bleaching reappeared in 1990. Most scientists suspect that bleaching of corals is caused by higher sea temperatures, although there is disagreement on this matter. If higher temperatures are the cause, marine scientists are unsure whether the phenomena is a natural one caused by periodic changes in currents, or whether the oceans are actually warming. NOAA researchers at the Atlantic Oceanographic and Meteorological Laboratory, Caribbean Marine Research Center, and NOAA's Climate and Global Change Program are actively involved in researching the phenomena (October 1990).

Massive Antarctic Iceberg Tracked by Satellite. A giant iceberg was tracked for 3 years by satellite along the Pacific coast of Antarctica. Formed from the Ross Ice Shelf, the Long Island-size iceberg drifted eastward for 1250 miles before breaking up. The big berg was tracked weekly by a combined effort involving the Navy/NOAA Joint Ice Center, Lamont-Doherty Geological Observatory, and New Zealand. Tracking the berg provided information on currents in the Ross Sea (October 1990).

Dr. Sylvia A. Earle Named NOAA's Chief Scientist. Dr. Sylvia Alice Earle, noted marine botanist and biologist, and co-founder and president of Deep Ocean Engineering Inc., of San Leandro, CA, was named Chief Scientist of NOAA. Dr. Earle is a world-renowned diver and expert on deep-sea operations, and has made major contributions to the evolving technology of underwater equipment (October 1990).

Pollutants in Northwest Sea Mammals Reported. Preliminary tests on marine mammals from the Pacific northwest and Alaska have shown surprisingly high levels of pollutants in some sea lions. NOAA's Northwest Fisheries Science Center has undertaken the study of tissues from stranded marine mammals to document the levels of contaminants such as PCBs, DDTs, and metals. What effects, if any, these contaminants have on the marine mammals is currently unknown. The tissue analysis will be archived in the newly established National Marine Mammal Tissue Bank (October 1990).

Estuaries of the United States Report Released. A special NOAA 20th anniversary report was released entitled "Estuaries of the United States: Vital Statistics of a National Resource Base." The report describes briefly the nation's estuarine resource base. It updates information presented in a number of previous NOAA reports and atlases developed through its National Estuarine Inventory, characterizing the nation's estuaries. The report was developed by NOAA's Strategic Environmental Assessments Division (October 1990).

Evidence of Recent Sea Floor Spreading Documented. Strong evidence of newly-formed ocean crust has been located off the Oregon coast at the southern end of the Juan de Fuca Ridge. Evidence includes a string of new volcanic mounds of lava and the occurrence of two large plumes of warm, mineral laden water. The evidence points to actual sea floor spreading resulting from plate tectonics. Marine gelogists and oceanographers at NOAA's Pacific Marine Environmental Laboratory made the discovery. Plans are being made to monitor the area in hopes of observing the events as they happen (November 1990).

Seasonal Ozone Depletion in Antarctic Atmosphere Increasing. The seasonal ozone "hole" over the South Pole appears to be increasing based on observations by NOAA's Climate Monitoring and Diagnostics Laboratory. Seasonal ozone depletion from August through December equaled the previous low set in 1978. The seasonal extent of the ozone hole has moved well into December unlike previous seasonal losses. Depletion of atmospheric ozone has been linked to chlorofluorocarbons (November 1990).

Coastal Contamination Report Released. A special report,"Coastal Environmental Quality in the United States, 1990: Chemical Contamination in Sediment and Tissues," was released by NOAA's Office of Oceanography and Marine Assessment to mark NOAA's 20th anniversary. The report, based on six years of results from the National Status and Trends Program and other monitoring efforts, describes the spatial extent and severity of chemical contamination and changes in concentration of contaminants over the last decade. While conclusions are always subject to new information, it appears that, on a national scale, high and biologically significant concentrations of contaminants measured by the NOAA monitoring program are limited primarily to urbanized estuaries. In addition, levels of contaminants have, in general, begun to decrease in coastal U.S. waters (November 1990)

Heard Island Experiment Studies Possible Ocean Warming. NOAA is participating in the underwater acoustic transmission experiment from Heard Island in the Southern Indian Ocean. Organized by Dr. Walter Munk of Scripps Institution of Oceanography, the study emitted pulses of sound for nine days and was monitored by numerous stations around the world. Seven nations, many agencies, institutions, and universities participated in the experiment. The experiment will study the greenhouse-induced changes in acoustic travel times which are directly related to changes in global sea temperature. NOAA provided funding, issued permits under the Marine Mammal Protection Act, and participated in marine mammal observations during the experiment (January 1991).

NOAA Supports Operation Desert Storm. In addition to assisting with Persian Gulf oil spills and fires, NOAA supported other aspects of Operation Desert Storm. NOAA's charting facilities were used by the Defense Mapping Agency to produce detailed maps of the Persian Gulf area for troops; NOAA's National Environmental Satellite, Data, and Information Service made satellite pictures of the area available to the major media outlets; and NOAA's National Weather Service provided historic weather statistics for the theater of war, including average monthly temperature, rainfall, and humidity (January 1991).

NOAA Scientists Assist in Interagency Persian Gulf Oil Spill and Oil Fire Assessment and Cleanup. Personnel from NOAA's Hazardous Materials Response Branch (HAZMAT) and Air Resources Laboratory (ARL) are part of the United States Interagency Gulf Response Team that is assessing the environmental damage to the Persian Gulf area. NOAA HAZMAT specializes in oil spill monitoring and modeling while ARL specializes in air quality monitoring (January 1991).

Sea Level Data From the Pacific and Indian Oceans Available. NOAA's National Oceanographic Data Center announced the availability of sea level data from the Pacific and Indian Oceans. These data are from a network of island-based and coastal tide gauges, many of which have been recording since the mid-1970s. The network includes stations from the Indo-Pacific sea level network as well as stations operated by many national and foreign agencies (February 1991).

NOAA, USGS to Study Great Lakes Erosion. A 10-year NOAA and U.S. Geological Survey (USGS) study will be conducted to assess erosion, sedimentation, and flooding in the Great Lakes basin. The pilot study will focus on the Lake Michigan shoreline, northward from the Michigan-Indiana border to Brenton Harbor, MI. This region is undergoing severe erosion, is subject to flooding, and lacks modern surveys of the nearshore area. NOAA will collect low-altitude aerial photography of the area to determine shoreline location and other technical details. USGS will collect seismic data, side-scan sonar data, core and bottom samples from nearshore waters, and surface and subsurface samples on land (February 1991).

Navy/NOAA Joint Ice Center Records New Maximum-Minimum Ice Extent. Ice edges reached new minimums and maximums in the Northern Hemisphere in the week ending February 16, 1991 reported the Navy/NOAA Joint Ice center of Suitland, MD. In the North Atlantic

Ocean, a new maximum ice extent was set reaching 60 miles farther south than the record set in April of last year. North of Japan, in the Sea of Okhotsk, a minimum ice extent was set, 3,000 square miles less than the record set in February 1976 (February 1991).

<u>Inconclusive Signs of Greenhouse Warming in the Central U.S.</u> Climatologists at NOAA's National Climatic Data Center reported there is no conclusive signs of greenhouse warming in the central United States, and it may take decades to determine the accuracy of models predicting that an enhanced greenhouse effect will make the central U.S. more drought-prone by the year 2030. The results of the analysis was published in the journal, <u>Science</u> (February 1991).

<u>El Nino/Southern Oscillation (ENSO) Advisory Issued.</u> NOAA's Climate Analysis Center issued an ENSO Advisory on February 11, 1991. The Advisory noted that a weak central Pacific warm episode had been in progress during the last year. However, persistent enhanced convection had failed to develop in the central equatorial Pacific and the atmospheric circulation features typical of warm episodes had not been observed. The depth of the thermocline and the upper-ocean heat content continue to be greater than normal in the equatorial Pacific (February 1991).

<u>Exxon Corporation, Federal Trustees Reach Out-Of-Court Settlement for Prince William Sound Oil Spill.</u> Federal trustees, led by the NOAA Administrator and the General Counsel, and the State of Alaska reached a $1 billion out-of-court settlement with Exxon Corporation for damage caused by the March 24, 1989 <u>Exxon Valdez</u> oil spill in Alaska's Prince William Sound. The criminal and civil settlement was the largest for environmental damages in U.S. legal history. The plea bargain agreement for the criminal charges was rejected by a federal judge in April 1991 and caused the settlement to be voided (February 1991).

<u>Invasion of Great Lakes by Zebra Mussels Studied by NOAA.</u> NOAA's Great Lakes Environmental Research Laboratory initiated a four-year study of the zebra mussel, an exotic species currently undergoing a population explosion in the Great Lakes region. The NOAA study will examine how the mollusk affects the aquatic food chain. The University of Michigan will participate in the study through NOAA's Sea Grant College Program (February 1991).

<u>Automatic Weather Observing System Planned.</u> Advanced, computerized weather observing systems will be installed this summer at airports in Oklahoma, Kansas, Nebraska, and Colorado, announced NOAA's National Weather Service. The new system, called the Automatic Surface Observing System (ASOS), will provide 24-hour weather observations at airports that close at night and at new stations. Other agencies involved in utilizing the new system along with NOAA are the Navy and Federal Aviation Administration. Installation of

ASOS nationwide is part of a long-term modernization of the National Weather Service (February 1991).

Buoy Network Spanning Tropical Pacific Planned for Summer. A two-year program to monitor ocean-atmosphere climate variables in the equatorial Pacific has been planned by NOAA's Pacific Marine Environmental Laboratory and National Ocean Service in conjunction with Japan and France. The buoy array will span 8,000 miles in length and 1,000 miles in width along the equator. Adding to the existing array of 18 moored instrument buoys, 65 additional moored stations will be installed. The buoys support instruments which measure surface wind, air temperature, relative humidity, sea surface temperature, subsurface water temperatures down to 500 meters, subsurface pressures, and near-surface salinity. The project will provide increased forecasting accuracy for ENSO events (March 1991).

Strategic Plan for Marine Turtle Tumor Research Released. A strategic research plan to investigate a mysterious disease that infects green sea turtles in epidemic proportions has been developed by NOAA scientists. The disease, fibropapilloma, produces tumors which can grow up to 12 inches in diameter, affecting turtle's eyes, mouth, throat and nasal passage, hindering breathing, feeding, and restricting movement. Although first documented in the 1920s, it was exceedingly rare until recent epidemics in Florida and Hawaii. Scientists from NOAA's National Marine Fisheries Service, universities and other federal and state agencies met in Honolulu and developed the research plan (March 1991)

Volunteer Weather Service Celebrates Centennial. Volunteers in NOAA's National Weather Service Cooperative Observer Program celebrated their 100th anniversary. The observer program was established in 1891 by the U.S. Weather Bureau, forerunner of the National Weather Service. It uses a network of more than 11,000 observers and 558 stations around the U.S. to measure temperature, precipitation, evaporation, and hydrologic information. The observers generate the main source of data for studying climate and are essential for long-term weather records in the United States (March 1991)

NOAA Steps Up Seafood Inspections. NOAA's National Marine Fisheries Service and the Food and Drug Administration announced a cooperative pilot program of special seafood inspections of seafood processing plants and other places that handle fish to check for contamination and other problems. The new inspection program is designed to enhance seafood safety to keep up with the increasing consumption of seafood by Americans (March 1991).

Regulations Proposed to Protect Sharks from Overfishing. Increased commercial fishing for sharks has endangered some species. NOAA's National Marine Fisheries Service is completing a management plan that will set federal fishing quotas for 39 species of sharks. Demand for shark meat and shark-fin soup has increased dramatically over the last 10 years, in part due to overfishing of swordfish and other billfish (March 1991).

Snake River Salmon Tentatively Declared as Endangered Species. NOAA's National Marine Fisheries Service tentatively listed Snake River salmon as protected under the Endangered Species Act (ESA). The comment period will last one year before a final decision is made on whether to formally list the species under the ESA (April 1991).

NOAA Bans Dolphin-Feeding Cruises. NOAA's National Marine Fisheries Service banned the feeding of marine mammals in an effort to stop the increasingly popular feeding cruises in which passengers toss food to marine mammals, such as bottlenose dolphins. The ban was implemented because feeding wild animals encourages dependency on humans and weakens natural behavior (April 1991).

Alaskan Oil Spill Clean-Up Increases Environmental Damage. The use of hot water under high pressure to remove oil from Alaska's beaches after the 1989 Exxon Valdez oil spill may have done more environmental harm than good and should be avoided in the future, according to a NOAA study. Oiled, but untreated, beaches had richer and more varied marine life than treated beaches and were similar in most instances to sites where no oil had come ashore (April 1991).

Methane Gas in Atmosphere Found to Have Longer Lifetime. Scientists at NOAA's Aeronomy Laboratory released findings that suggest methane's contribution to the greenhouse effect is larger than previously thought. New calculations show that methane stays in the atmosphere approximately 25 percent longer than originally believed, about 12.5 years instead of about 10 years. The results were published in the journal, Nature. Methane is an important greenhouse gas as its relative contribution to the greenhouse effect is second only to carbon dioxide (April 1991).

U.S. Judge Rejects Exxon Oil Spill Fine as Inadequate. A U.S. District Court judge in Alaska last week rejected the $100 million criminal fine negotiated between the federal government and Exxon Corporation over the Exxon Valdez oil spill throwing the entire $1 billion settlement into doubt. Five federal agencies, including NOAA, are charged under federal law with protecting the country's natural resources and had announced the settlement in February. The $100 million criminal fine was part of a total $1 billion settlement. It included $900 million to the trustees, as well as the State of Alaska, for several purposes: a science program; restoration planning and pilot projects; reimbursement for most of the trustees, including NOAA, for past expenses; and restoration efforts aimed at returning Prince William Sound to its pre-spill condition (April 1991).

<u>NOAA Establishes New Florida Keys National Marine Sanctuary.</u> The nation's newest and largest marine sanctuary, the Florida Keys National Marine Sanctuary, was established in the Florida Keys by NOAA's Sanctuaries and Reserves Division. The sanctuary covers 2,600 square nautical miles of tropical coral reefs, algal reefs, sea grass beds, and archeological sites (April 1991).

<u>Soot Detected over Hawaii by NOAA Observatory May Be from Kuwait.</u> Air samples taken at NOAA's mountaintop Mauna Loa Observatory in Hawaii contained small amounts of soot particles which could have been from the oil fires in Kuwait. Highly absorptive particles presumed to be carbon were found in normally clean tropospheric air samples routinely taken at the observatory. The observatory is operated by NOAA's Climate Monitoring and Diagnostics Laboratory in Boulder, CO (May 1991).

<u>CFC and Halon Substitutes Evaluated by NOAA Research Team.</u> Chemicals intended to replace ozone-destroying chlorofluorocarbons (CFCs) and halons have drawn mixed reviews from researchers at NOAA's Aeronomy Laboratory. Replacement chemical hydrochlorofluorocarbon (HCFC-141b) has an ozone-depletion potential about 50 percent larger than previously believed due to a miscalculation of its atmospheric lifetime. Recent calculations place its lifetime at about two-thirds greater than the previous estimate of eight years, a lifetime similar to presently-used CFCs. Another chemical, FM-100, a halon replacement, only lingers in the atmosphere 7 to 8 years compared to the 80 years for halogens making it a better substitute (May 1991).

<u>Global Precipitation Declines in 1980s.</u> Yearly precipitation over land areas declined in the 1980s following a three-decade period of increase, a comprehensive set of NOAA rain and snowfall records revealed. Preliminary analysis of information collected from 5,328 stations around the world indicates a period of predominantly dry conditions existed from the late 1800s to about 1950, followed by about 30 years of wetter conditions. The peak precipitation during this 30-year period was experienced around 1955 and again predominatly in the mid-1970s. A return to drier conditions occurred by the mid-1980s. The analysis was performed by NOAA's Climate Monitoring and Diagnostics Laboratory (May 1991).

<u>Weather/Climate Satellite Launched into Polar Orbit Is a Success.</u> NASA and NOAA launched NOAA-12, a new polar-orbiting operational environmental satellite which will gather weather and climate data from 450 miles above the Earth. Successfully launched from Vandenberg Air Force Base, CA, the satellite is the latest of NOAA's weather satellites. NOAA-12 will collect and transmit data automatically to ground stations in 122 countries. NOAA-12's data will help scientists to continue studying a variety of critical

environmental issues including ozone depletion, acid rain, ocean pollution, and climate change. NASA managed the spacecraft production and launch for NOAA (May 1991).

Shellfish Contaminated by Red Tide. NOAA's National Marine Fisheries Service and the U.S. Food and Drug Administration issued a warning to local fishermen not to eat shellfish from the Georges Bank. The bivalves, which can accumulate high levels of the toxin that causes paralytic shellfish poisoning, may in some cases be fatal (May 1991).

Solar Flares Cause Severe Geomagnetic Storm. Solar flares caused the most intense geomagnetic storm since 1989 to strike the Earth, threatening electrical power distribution, satellite operations and communication systems. NOAA's Space Environment Services Center in Boulder, CO, reported the storm, which began June 4, increased in intensity overnight, and was rated "severe" by the next day. Fewer than five percent of geomagnetic storms reach that strength. The solar event resulted in the aurora borealis being visible as far south as the latitude of New York City. Interference with high-frequency radio transmission was spotty, with some areas of the U.S. and Canada experiencing fading of transmissions while other areas saw intensification (June 1991).

Tornadoes Reach Record Numbers. The number of tornadoes reported as of June 1991 have set a record for this time of year, according to NOAA's National Severe Storms Forecast Center in Kansas City, MO. More then 1033 tornadoes had been reported as of June 10 compared with 841 for the same period last year. The report of 1,132 tornadoes in 1990 in the lower 48 states beat a record last set in 1973 (June 1991).

NOAA Reports Effects of Drift-Net Fishing. NOAA's National Marine Fisheries Service reported that Japanese drift-net fisheries killed millions of fish last year in the north Pacific, including more than 9,000 salmon, over 30,000 thousand sea birds, over 250,000 tuna, almost 82,000 sharks, and nearly 2,000 marine mammals, and 35 sea turtles. More than 3 million other non-target fish were also killed. The report covered bycatch kills documented by scientific observers aboard only 10 percent of Japan's fishing vessels. The drift-net fishery was described as "indiscriminately lethal" (June 1991).

NOAA Monitors Effect of Volcano Eruption on Global Climate. The eruption of Mount Pinatubo in the Philippines, perhaps the largest volcanic eruption this century, may have significant effects on global climate according to NOAA researchers. The stratospheric plume, in addition to perhaps depressing global temperatures, could alter stratospheric ozone chemistry reported scientists at NOAA's Aeronomy Laboratory. NOAA weather satellites were used to track the stratospheric aerosol plume around the Earth (June 1991).

Atmospheric Carbon Monoxide Estimates May be Inaccurate. NOAA's Climate Monitoring and Diagnostic Laboratory reported that a widely-used carbon monoxide reference gas was found to vary in comparison tests by almost 25 percent. Because of this, atmospheric scientists using computer projections to model global climate changes may be underestimating the amount of carbon monoxide in the atmosphere by as much as 25 percent. The results were reported in the Journal of Geophysical Research. Carbon monoxide, unlike carbon dioxide, is not a significant greenhouse gas, but is associated with important chemical interactions involved in the greenhouse effect (June 1991).

Atlantic Swordfish Protection Proposed. NOAA's National Marine Fisheries Service announced emergency regulations to protect and restore the declining Atlantic swordfish population. The plan will allow fisherman to catch three million pounds of swordfish during each of two six-month periods. The quotas are based on 1990 recommendations by the International Commission for the Conservation of Atlantic Tunas (June 1991).

NOAA Coordinates Interagency Project on Past Climates. NOAA's National Geophysical Data Center is coordinating an interagency project to study 500 years of climatic data to document effects of two key historical climatic cooling events: very low sunspot activity from 1680 to 1715 and the eruption of Tambora volcano in 1815. Among the records to be checked are tree rings, lake and marine sediments, corals and glacial ice cores. Computer models will be run to determine the cause of the 400-year period (1450 to 1890) of global cooling called the "little ice age" (June 1991)

El Nino/Southern Oscillation (ENSO) Advisory Issued. The latest ENSO Advisory from NOAA's Climate Analysis Center showed that during the last several months, the trend in sea surface temperature (SST) in the equatorial Pacific from 160°E eastward to 160°W, has been indicating the development of a warm episode. However, enhanced persistent atmospheric convection has not yet become established in the central equatorial Pacific. As the Northern Hemisphere warm season comes to a close, tropical convection will begin shifting toward the equator (August 1991).

New National Marine Sanctuaries Progress Toward Reality. The nation's two newest National Marine Sanctuaries (NMS) moved closer to designation with the release of environmental impact statements (EIS). A draft EIS was released for public comment for the Olympic Coast NMS and a management plan and final EIS was released for comment for the Flower Gardens NMS. The Olympic Coast NMS covers 3,400 square miles off the scenic coast of Washington. The Flower Gardens NMS, located about 115 miles southeast of Galveston, Texas, protects the northernmost coral reefs in the Gulf of Mexico (August 1991).

NOAA Leases European Weather Satellite to Assure Forecasting Capability. NOAA, the European Space Agency, and the European Meteorological Satellite Consortium agreed to the use of the European Merosat-3 meteorological satellite to back up U.S. weather forecasting capabilities. The agreement will allow NOAA's National Weather Service to provide continuous monitoring of weather from space in case the aging U.S. GOES-7 weather satellite reaches the end of its scheduled lifetime early in 1992. The first replacement for the U.S. GOES satellites will not be available until late 1993 or early 1994 (September 1991).

New Exxon Valdez Settlement Approved. A federal judge approved a new plea bargain agrement for the 1989 oil spill in Prince William Sound, Alaska. The penalties, higher than those rejected in an April 1991 ruling, are the highest ever assessed in the U.S. for environmental damages. A portion of the penalties will be allocated to NOAA for funding damage assessment and habitat restoration projects (October 1991).

NOAA Lawsuit Provides For Environmental Improvements. A lawsuit filed by NOAA provides for the cleanup of Elliott Bay and parts of the Duwamish River in Puget Sound, Seattle, Washington. The cleanup calls for capping or removing metals and oil products that have built up over decades in nearshore waters to levels poisonous to fish and shellfish and for restoring fish habitat. The settlement involves federal, Washington State, native-American tribes, and local governments. The settlement is the largest ever for a marine contamination case, excluding oil spills. NOAA has responsibility to recover natural resource damages under the Comprehensive Environmental Response Compensation and Liability Act (October 1991).

Future North America Vegetation Changes Predicted by NOAA. The next two centuries may produce unprecedented vegetation changes in the Northern Hemisphere if projected future climate warming occurs. Some plant ranges could shift as much as 500-1000 km during the next 200 to 500 years and could have dramatic impacts on forest and other ecosystems. The climate-pollen analysis model was published in the journal, Science, by scientists from NOAA's National Geophysical Data Center (November 1991).

Snake River Sockeye Salmon Designated an Endangered Species. The National Marine Fisheries Service of NOAA formally designated the Snake River sockeye salmon as an endangered species. The designation initiates a federal program to restore the species population (November 1991).

Gray Whale Population Recovers. The California gray whale population has recovered to numbers at least as many as, or more than, existed prior to the peak of commercial whaling in the mid-nineteenth century. The findings were announced by Dr. John Knauss, Administrator of NOAA. California gray whale numbers have been growing at about 3 percent annually and are now estimated at about 21,000 individuals. NOAA's National Marine Fisheries Service monitors the abundance of California gray whales under the Endangered Species Act and Marine Mammal Protection Act (November 1991).

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